modern castings

OCTOBER 1958

The Foundrymen's Own Magazine

Circle No. 955, Page 7-8

future meetings and exhibits

OCTOBER

8-10 . . Gray Iron Founders' Society, *Annual Meeting*. Sheraton Park Hotel, Washington, D. C.

13-18 . . National Industrial Sand Association, *Semi-annual Meeting*. The Greenbrier, White Sulphur Springs, W. Va.

14-16 . . Society of Industrial Packaging & Materials Handling Engineers, *Annual Packing, Handling & Shipping Show*. Coliseum, Chicago.

15-16 . . AFS *Michigan Regional Foundry Conference*. University of Michigan, Ann Arbor, Mich.

16-17 . . AFS *All Canadian Regional Foundry Conference*. Royal Connaught Hotel, Hamilton, Ont.

16-17 . . Magnesium Association, *14th Annual Convention*. Fort Shelby Hotel, Detroit.

16-18 . . Foundry Equipment Manufacturers' Association, *Annual Meeting*. The Greenbrier, White Sulphur Springs, W. Va.

17-18 . . AFS *New England Regional Foundry Conference*. Massachusetts Institute of Technology, Cambridge, Mass.

18-21 . . Conveyor Equipment Manufacturers Association, *Annual Meeting*. The Greenbrier, White Sulphur Springs, W. Va.

20-24 . . National Safety Council, *46th National Safety Congress*. Conrad Hilton Hotel, Chicago.

20-24 . . National Association of Corrosion Engineers, South Central Region, *Conference & Exhibition*. Roosevelt Hotel, New Orleans.

22-23 . . National Management Association, Annual Meeting. Statler-Hilton Hotel, Los Angeles.

22-24 . . American Ceramic Society, *Pacific Coast Regional Meeting*. Ambassador Hotel, Los Angeles.

27-30 . . Metallurgical Society of American Institute of Mining, Metallurgical & Petroleum Engineers, *Fall Meeting*. Carter Hotel, Cleveland.

27-31 . . American Society for Metals, *National Metals Exposition & Congress*. Public Auditorium, Cleveland.

30-31 . . AFS *Purdue Metal Castings Conference*. Purdue University, West Lafayette, Ind.

31-Nov. 1 . . AFS *Northwest Regional Foundry Conference*. Multnomah Hotel, Portland, Ore.

NOVEMBER

10-12 . . Steel Founders' Society of America, 13th *Technical & Operating Conference*. **Carter Hotel, Cleveland.**

20-21 . . National Foundry Association, *Annual Meeting*. Drake Hotel, Chicago.

30-Dec. 5 . . American Society of Mechanical Engineers, *Annual Meeting*. Statler Hilton and Sheraton-McAlpin Hotels, New York.

DECEMBER

3 . . Foundry Facings Manufacturers Association, *Annual Meeting*. Waldorf-Astoria Hotel, New York.

3-5 . . American Institute of Mining, Metallurgical & Petroleum Engineers, *Electric Furnace Steel Conference*. Statler Hotel, Detroit.

3-5 . . National Association of Manufacturers, *Annual Meeting*. Waldorf-Astoria Hotel, New York.

9 . . Material Handling Institute, *Annual Meeting*. New York.

1959

FEBRUARY

12-13 . . AFS Wisconsin *Regional Foundry Conference*. Schroeder Hotel, Milwaukee.

15-19 . . American Institute of Mining, Metallurgical & Petroleum Engineers, *Annual Meeting*. San Francisco.

26-27 . . AFS *Southeastern Regional Foundry Conference*. Hotel Tutwiler, Birmingham, Ala.

MARCH

9-10 . . Steel Founders' Society of America, *Annual Meeting*. Drake Hotel, Chicago.

11-12 . . Foundry Educational Foundation, *Annual College-Industry Conference*. Hotel Cleveland, Cleveland.

13-14 . . AFS *California Regional Foundry Conference*. Huntington-Sheraton Hotel, Pasadena, Calif.

16-20 . . American Society for Metals, *11th Western Metal Exposition & Congress*. Pan-Pacific Auditorium and Ambassador Hotel, Los Angeles.

APRIL

13-17 . . AFS *2d Engineered Castings Show and 63d Annual Castings Congress*. Hotels Sherman and Morrison, Chicago.

MAY

13-15 . . National Industrial Sand Association, *Annual Meeting*. The Homestead, Hot Springs, Va.

25-26 . . Malleable Founders' Society, *Annual Meeting*. The Homestead, Hot Springs, Va.

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october, 1958
vol. 34, no. 4

modern castings

features

departments

featurettes

editor's report

by Jack Schaum

■ "There is a 125 million dollar market for investment castings in aircraft and missile applications," according to J. K. Dietz, Chance Vought Aircraft Inc., in a talk before the Investment Casting Institute. This potential business exists if foundrymen can cast shapes 36 to 48 in. long with minimum sections of 0.1 to 0.08 in., 260,000 psi tensile strength, 210,000 psi yield strength and 4 per cent elongation. Now there's a big target worth shooting for!

■ This market is not just limited to investment casters either. In this issue of Modern Castings you can read about how Osbrink Manufacturing Co. is now casting aluminum and magnesium aircraft and missile components in sand with wall thicknesses down to 0.050 in., as-cast tolerances of ± 0.0050 in. and 100 rms or better micro-finish!

■ "We can run our new water cooled cupolas acid, neutral or basic all in the same day's campaign," says Dick Aylward of Neenah Foundry, Neenah, Wis. In fact, it is quite a common practice for them to start off in the morning producing gray iron with an acid practice, and then switch over to neutral or basic operation and start tapping low sulfur high carbon iron suited for nodular iron castings. Only a few minutes time and about 1000 lb of transition metal are consumed making the change!

■ Improved heat conductivity for epoxy resins has long been the goal of the manufacturers and a need of the foundry industry. Epoxy patterns get hot and stay hot when contacting hot molding sands: ergo, sand starts to stick to pattern. Epoxy dies for wax injection by investment casters conduct the heat away from the molten wax too slowly. Higher conductivity might even permit epoxy patterns to be used for shell molding. A prominent resin formulator has come up with a partial solution to the problem that shows promise. Steel fibers are given the optimum directional orientation for heat flow away from pattern surface by applying a magnetic field. With fibers standing on end, liquid epoxy is poured around them. Fibers are locked in position by hardening resin. It is claimed the resulting material has a heat conductivity equal to 304 stainless steel!

Arc Plus Air Cleaning for Less Noise, Higher Output

by ARTHUR HARE
Grede Foundries, Inc.
Milwaukee

The arc-air process is being used in our foundry wherever possible and profitable, not only as an increase to our production but also to eliminate chipping noise. At the present time we are removing fins from 50 per cent of our production and pads from 25 per cent.

A torch to handle 3/8-in. electrodes was purchased first to remove crack defects from castings. Upon seeing its potential, two more torches handling 1/2-in. electrodes were installed in our turntable welding booths for the removal of defects and internal pads. This was followed by the installation of an arc-air torch in every welding booth.

Experiments with fin and pad removal in the welding booths soon proved successful. After some experimenting it was decided to use motor generators as a source of power for the new torches. Two 1000 ampere, constant potential motor generators and one 1200 ampere machine are now in service.

From information gained in previous welding booth experiments, it was decided that supervisors should become arc-air operators before attempting to train anyone. It was decided that chippers, rather than welders, having the proper removal know-how and being most concerned with arc-air due to the probable loss of their jobs, would be best suited to train. After one week's training our first operator was on his own and he became instructor for the operators that were to follow.

Pads as small as 1-1/2 x 3-in. to as large as 38-in. diameter have been removed with substantial savings in labor costs effected. By the use of the wrong technique, the operator can increase the amperage required to remove a given amount of metal and also increase the time needed to remove this given amount of metal. The operator must acquire a smooth, fluid motion in his handling of the torch. Light enough to avoid abuse of the equipment and yet heavy enough to effect metal removal at a steady, even flow—not giving slag a chance to build up and impede the progress of his work. It is of great help to the operator if he is equipped with a jitterbug-type slag removal hammer like those used in conjunction with the removal of welding slag and scale. With the use of this tool he can greatly reduce the heat

abuse and amperage resistance set up by slag mounds.

To thoroughly remove fins with the arc-air process, a much better blast or abrasive cleaning job is needed than was necessary for chipping. Even with this better cleaning we still do not arc-air those castings that are burned on at the base of the fins. Any attempt to arc-air sand—included areas causes the arc to gouge or dive under the sand line, removing portions of the castings. This type of fin removal is now handled at powder wash stations. Sand defect removal is limited to small areas because an excess of metal must be removed in order to get rid of it. Crack removal by arc-air is being used extensively in preference to the old, tedious method of chipping out crack defects.

Equally as important as the production problems is the big problem of maintenance. Maintenance centers around dust removal, brushes and torches. Each machine is checked thoroughly once a week by the maintenance department. It is completely blown out, checked for shorts and the brushes closely inspected and replaced if necessary. To avoid being a part of the normal shop waiting list for maintenance, we trained cleaning room personnel to handle this maintenance.

■ Condensed from a talk presented at 21st Wisconsin Regional Foundry Conference.

product report . . .

Makes furnace additions . . . to open top of electric arc furnaces for Atlantic Seaboard Div. plant, Charleston, South Carolina. Specially designed Blaw-Knox Dolomite machine is the first of its kind manufactured

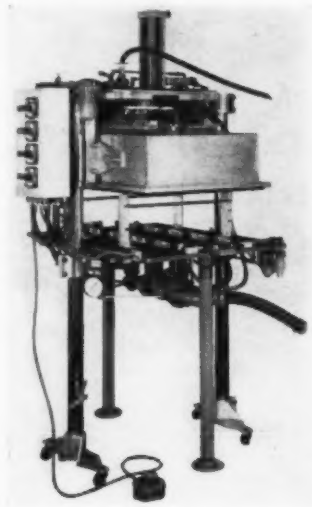
by Blaw-Knox Co., Pittsburgh, Pa. Company officials say that the hydraulic throwing mechanism, energized by truck's power take-off, can handle a variety of materials in addition to dolomite. Mechanism can be related 180 degrees; 40 cu ft capacity.

For Manufacturer's Information Circle No. 943, Page 7-8

Build an idea file for plant improvements. The post-free cards on page 7-8 will bring more information on these new . . .

products and processes

CO$_2$ MOLD CURING . . . gassing unit reportedly cures molds stripped or on the pattern. Features adjustable height, blank-off-blocks which re-



duce excess chamber space and stop cam for arresting inward movement of mold. *Alphaco, Inc.*

For Manufacturer's Information Circle No. 861, Page 7-8

VIBRATION-FREE BARREL FINISHING . . . claimed for new equipment reported to be so stable that a coin balanced on edge on housing will remain standing throughout operating cycle. Said to offer greater convenience in loading, unloading and cleaning; and to be ideal for deburring, descaling and burnishing. *Wheelabrator Corp.*

For Manufacturer's Information Circle No. 862, Page 7-8

CHECKS INSIDE LEVEL . . . of material in furnace. Electronic device uses nuclear energy to keep constant automatic check by projecting gamma rays through furnace to Geiger counters. All components outside furnace. Signal actuates automatic furnace controls, or registers on control board. Source's useful life, 3 years; replacement is inexpensive, according to manufacturer. *Nuclear Corp. of America.*

For Manufacturer's Information Circle No. 863, Page 7-8

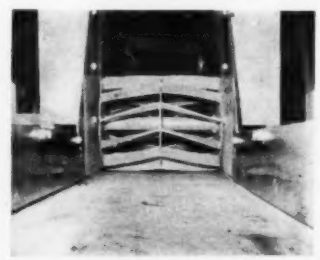
MAGNETIC DRILL PRESS . . . can be clamped to any ferrous surface. Designed to accommodate all makes and models of portable air and electric drills equipped with dead-handle sockets. Features swivel column with lock, permitting accurate location of work. *Thor Power Tool Co.*

For Manufacturer's Information Circle No. 864, Page 7-8

INFRA-RED OVEN PANELS . . . for foundry applications such as rapid curing of epoxy resins, drying sand and baking cores. Designed for construction of radiant surfaces for use over conveyor belts and as walls, ceilings and floors of furnaces. Infra-red radiation reportedly not color selective, with absorption high. *Industrial Process Div., Ampere Industries.*

For Manufacturer's Information Circle No. 865, Page 7-8

CLAY BALL PROBLEM . . . in mulling operations reduced and in some cases eliminated completely by two-wheeled blender with mitered cutter wheels, according to manufacturer.



Unit thoroughly distributes clay with sand before water is added. Officials claim greatly improved sand properties by placing unit before muller on conveyor belt. *Pekay Machine & Engineering Co.*

For Manufacturer's Information Circle No. 866, Page 7-8

SPECTROMETER . . . shows ferrous and non-ferrous metals and alloys

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analysis within 30 sec. Gives instant direct reading of up to 30 alloying elements. Design permits optional film recording of analytical spectrum. Said not to require prolonged operator training, to have easily serviced plug-in componets, and extreme temperature stability. *Jarrell-Ash Co.*

For Manufacturer's Information
Circle No. 167, Page 7-8

REFRACTORY SAW . . . for trimming refactory bricks now has an attachment allowing unit to be easily moved about the plant. A wheel kit permits wheels to be quickly assembled on the rear legs of lever arm. Brick-saw can then be moved as you would maneuver a wheelbarrow. *Eveready Bricksaw Co.*

For Manufacturer's Information
Circle No. 868, Page 7-8

SWEAT BAND . . . has been tested to evaporate 27-60 per cent more moisture than competitive models, aiding in preventing blurry vision and sweat-fogged glasses or goggles, manufacturer claims. Cooling affect afforded by perforations in sponge-like strip of cellulose acetate. Evaporation may be increased by dipping sweat band in cold water prior to wearing. Easily cleaned with soap and water. *Sellstrom Mfg. Co.*

For Manufacturer's Information
Circle No. 869, Page 7-8

VERTICAL BLUEPRINT FILING . . . of single sheets; also plans, maps and drawings. Hangs each sheet individually, free of wrinkles or creases, ready for instant identification and use. Wall-mounted bracket accommodates up to 150 aluminum hangers in 12-in. width. *Plan Hold Corp.*

For Manufacturer's Information
Circle No. 870, Page 7-8

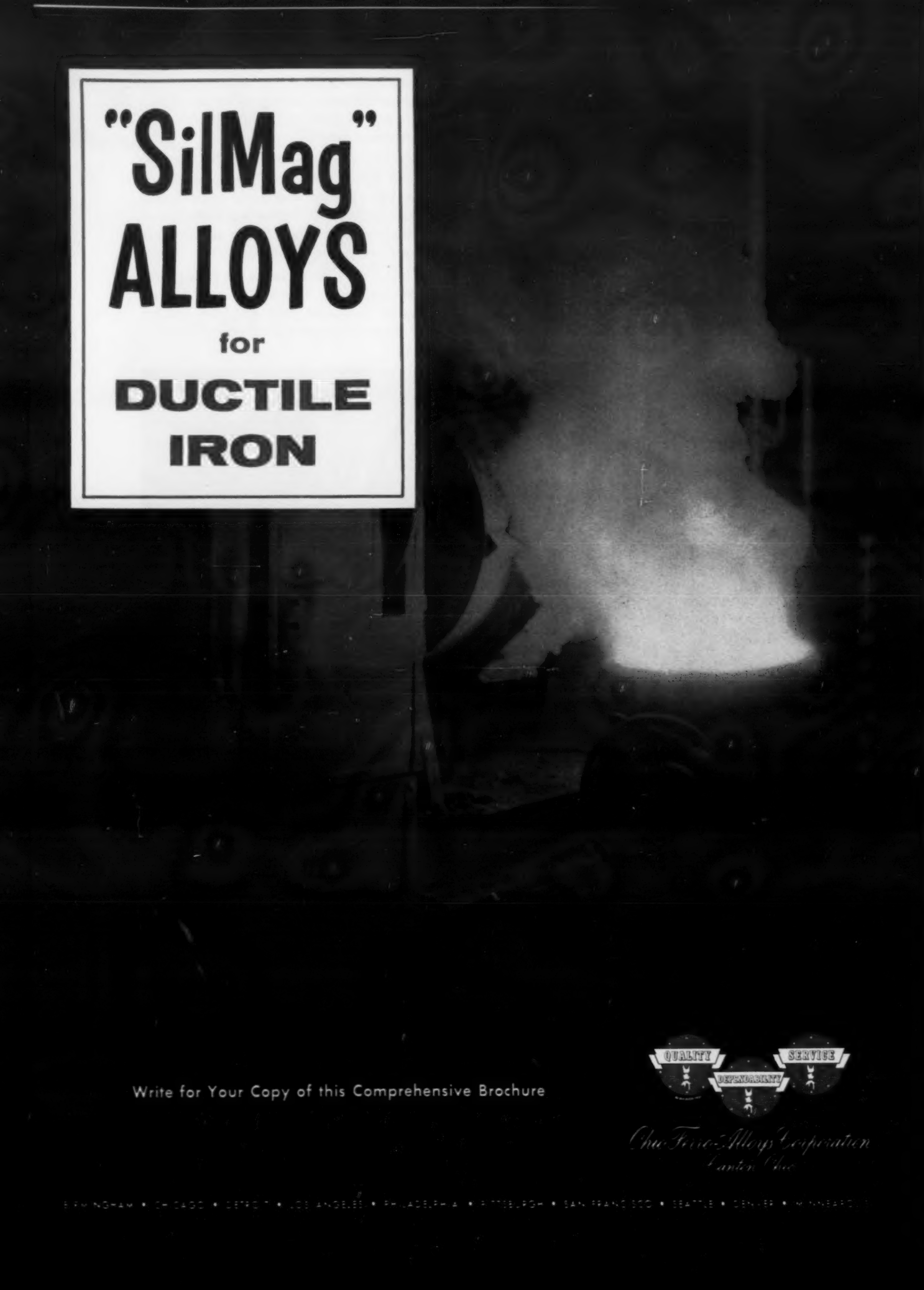
CONTACT WHEEL . . . self-aligning, for abrasive belts is made of rubber, and is said to need no aligning even when spindles are worn. Manufacturer claims rubber hub gives effect of floating power, eliminating vibration and providing contact wheel at lower cost than conventional types. *Chicago Rubber Co.*

For Manufacturer's Information
Circle No. 871, Page 7-8

SEALANT . . . designed for threaded connections, flanged joints and gaskets in contact with petroleum-base oils, ethylene glycol, water and gasolene. Said to be highly vibration resistant. *Permatex Co.*

For Manufacturer's Information
Circle No. 872, Page 7-8

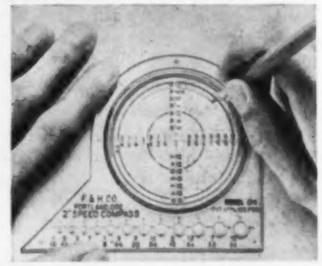
ALUMINUM ROOF COATING . . . is claimed to give greater roof coverage characteristics, give longer protection, improve building appearance, minimize roof maintenance, cut under-roof temperatures and improve



air conditioning efficiency. Tests indicate product equally effective on felt, tar paper, gravel or composition roofs, pitched or flat. *Monroe Co.*

For Manufacturer's Information Circle No. 873, Page 7-8

BALL BEARING COMPASS . . . precision drafting instrument permits drawing of perfect circles, 1/4 to



2-in. diameters by inserting pencil in desired hole and spinning around center. Offers choice of 69 diameters. *F & H Mfg. Co.*

For Manufacturer's Information Circle No. 874, Page 7-8

IMPREGNATION EQUIPMENT . . . lease plan for castings producers who feel production does not justify purchasing this equipment. Will permit producers and users of castings to test before they buy. Equipment from basic leak testers to fully automated impregnation machinery is available on leasing basis. *Prenco Mfg. Corp.*

For Manufacturer's Information Circle No. 875, Page 7-8

ASBESTOS GLOVES . . . reportedly allow handling of steel at 1200 F with safety and ease. Treated with special aluminum-resin coating. Officials report increased heat resistance plus up to four times longer wear. *Mine Safety Appliances Co.*

For Manufacturer's Information Circle No. 876, Page 7-8

EDDY CURRENT . . . testing instrument locates and determines relative seriousness of defects in all conductive materials, according to manufacturer. Sorts mixed lots of ferrous and non-ferrous metals for differences in hardness, alloy and heat treat condition. Measures thickness of certain conductive and non-conductive coatings. *Magnaflux Corp.*

For Manufacturer's Information Circle No. 877, Page 7-8

INDUCTION MELTING . . . through simple unit for converting frequency. Unit is a static-frequency multiplier, taking, for example, 3-phase power at 60 cycles directly from ordinary supply line and delivering single-phase power to furnace through con-

Circle No. 961, Page 7-8

ventional lines. Company claims furnace power supply cost is two-thirds to three-quarters that of conventional motor-generator type equipment. Operation said to be almost automatic and easy for inexperienced operator use. *Ajax Electrothermic Corp.*
For Manufacturer's Information Circle No. 878, Page 7-8

METAL-FILLED EPOXY . . . resins designed to make strong castings with properties similar to metal. Make molds for short-run use and for filling voids and plugging holes in metal structures, wood, plastics. Two-component material cures at room temperature and is said to have excellent machining properties. Sets in four hr at 70 F and in one hr at 120 F. *American Latex Products Corp.*
For Manufacturer's Information Circle No. 879, Page 7-8

RESONANCE BONDING . . . of mold and core sands hardens sand without use of heat, ovens or gassing equipment. Manufacturer claims setting and hardening time can be adjusted to suit individual needs by means of "delayed chemical action," and that materials and principles of new process reduce hardening time of shell molds.Process claimed to increase size and reduce cost of investment castings, and to result in use of finer sands. *Coldhard-HiUtek Div., United States Trading & Service Corp.*
For Manufacturer's Information Circle No. 880, Page 7-8

EPOXY MOLDING . . . compound reportedly offers for the first time high strength coupled with exceptional conformability. Users report average flexural strength of 100,000 psi, average tensile strength of 40,000 psi and average compressive strength of 38,000 psi at normal temperatures. Glass content, 66 per cent; resin content, 34 per cent. Manufacturer states that once molded, the material offers the good dimensional stability characteristic of epoxy resins. *Minnesota Mining & Mfg. Co.*
For Manufacturer's Information Circle No. 881, Page 7-8

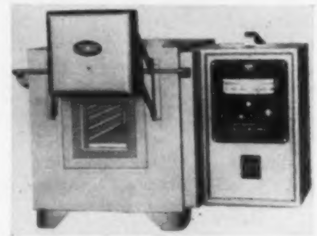
SHELL MOLD . . . release agent eliminates sticking, break-in, build-up and cleaning of shell mold patterns and core boxes. Applied by spray or brush, coating tested to withstand temperatures over 1000 F. Smokeless, non-toxic and inert, material said to be an effective high temperature lubricant. *Chem-Cote Co.*
For Manufacturer's Information Circle No. 882, Page 7-8

NEW X-RAY INSPECTION . . . unit with fluoroscopy 10,000 times brighter than conventional types, is manufacturer's claim. Product will make possible 100 per cent production line

quality control x-ray inspection, officials state. Closed-circuit television image intensification system. *General Electric Co., X-ray Dept.*

For Manufacturer's Information Circle No. 883, Page 7-8

ELECTRIC FURNACE . . . bench type high temperature models feature chamber size which is long in relation to its height and width, eliminating "waste" space. Designed so that



user need not buy over-size furnace to accommodate relatively long work loads. Power, 115 or 230 volts. Operating temperatures, 2000 or 2300 F. *Thermo Electric Mfg. Co.*

For Manufacturer's Information Circle No. 884, Page 7-8

ON-THE-SPOT LABELS . . . of metal or plastic possible with portable hand embosser. Makes permanent labels of any desired length with raised characters or letters on self-feeding metal

or colored plastic strip housed in handle. Adhesive backing on both the metal and the plastic will stick firmly to any smooth surface. *Roovers-Lotsch Corp.*

For Manufacturer's Information Circle No. 885, Page 7-8

FOLD-UP SCAFFOLD . . . all steel, light-duty, has 28-in. over-all width, is 5 ft high and has 4-ft plywood platform. Folds up neatly for hauling atop car. Platform may be placed on any rung desired. *Bil-Jax, Inc.*

For Manufacturer's Information Circle No. 886, Page 7-8

FINE SCREEN CLEANING . . . by ultrasonic unit. According to manufacturer's tests, a U.S. 325-mesh screen used to sift silica sand (over 100,000 apertures per sq in.) was completely freed of sticking sand particles in one min. Process consists of dipping screen into tank containing water and detergent and applying high-frequency vibrations. *Narda Ultrasonics Corp.*

For Manufacturer's Information Circle No. 887, Page 7-8

have you read . . . ?

American Society for Testing Materials, Proceedings, Philadelphia, 1957, v 57, 1430 pp.

Herein are recorded the technical accomplishments of the year, the reports, the papers, together with discussion offered to the society during the year. In the volume is the annual president's address, "Our Expanding Technology and A.S.T.M." On page 1409 is listing of the Society's special technical publications, and elsewhere in the book are all the papers which were published in the A.S.T.M. Bulletin.

Gagnebin, Albert P., **The Fundamentals of Iron and Steel Castings,** The International Nickel Company, 1957, 78 pp.

Book is concerned with the various grades of iron and steel, their characteristics, their mechanical properties and casting considerations. For the ferrous engineer, there are chapters on cast steel, on gray cast iron, white cast iron, malleable iron and ductile iron. Phase transformation and solidification is a distinct chapter.

Pearson, W. B., **A Handbook of Lattice Spacings and Structures of Metals and Alloys.** Pergamon Press, New York, 1958, 1044 pp.

This is a reference work for the physicist and metallurgist. It examines the lattice spacings of the vast majority of binary and ternary alloys. The chapters are organized into two parts: I. Chapters dealing with x-ray investigation of metals and alloys. II. Chapters assessing the work done thus far in the field of x-ray of alloys in equilibrium. There is classifying of intermetallic phases according to structure type, while a separate alphabetical index is set up for work on metals and alloys, another for work on borides, carbides, hybrids, nitrides and binary oxides.

Light Metals and Alloys Standards, American Society for Testing Materials, Philadelphia. 1958, 320 pp.

This compilation of A.S.T.M. Standards covers the methods for testing light metals. Not only those specifications and methods of test which come under the jurisdiction of Committee B-7, but also those for die castings as prepared by Committee B-6, and those for aluminum wire and cable for electrical purposes as sponsored by Committee B-1. Among the general topics covered are: ingots, castings, bars, rods, wire, shapes, forgings, pipes, tubes, sheet, plate, wrought products, filler metal and electroplating. Of the 51 standards, 36 are new, revised or have had their status recently changed.—*A. C. Lohse*

Circle No. 964, Page 7-8

patent review

For more information on the Osbrink Process, read the feature article beginning on page 22.

R. H. Osbrink has patented his method of producing large, hollow, thin-walled non-ferrous castings.

The method consists of producing the pattern as a sectional construction, rather than as a large, single construction. Similarly, cope and drag flask sections are provided for each pattern section, rather than a single, large cope and drag flask.

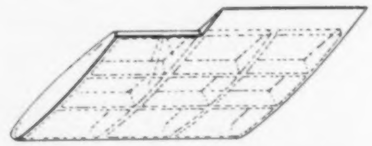


Fig. 1 . . Typical thin-wall casting.

These smaller mold sections can be produced almost simultaneously and can have uniform green strength. The weight of individual sections is far less than the weight of the total, and is easier and safer to move.

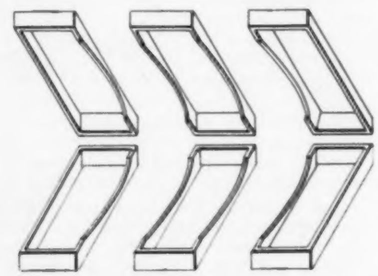


Fig. 2 . . Sectional cope and drag.

Cores are placed in the drag mold sections before the sections are assembled into the complete mold. This procedure permits inspec-

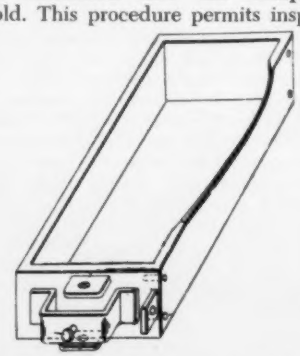


Fig. 3 . . Detail of sectioned flask.

tion of clearances between the core and the mold.

Figure 1 illustrates a simplified typical casting to be produced by this patented process. Figure 2 shows the sectional mold with cope and drag sections.

Figure 3 shows an important detail of the invention: the sides of the flask are cut away to the same

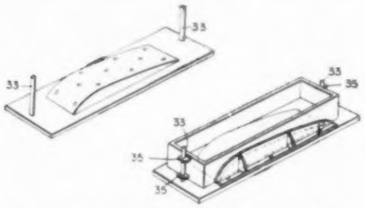


Fig. 4 . . Pattern section and flask.

general contour as the pattern but the cut-away edges will be covered with sand when the mold is rammed.

Figure 4 (left) shows a pattern section and Fig. 4 (right) shows the pattern assembled in the drag flask. Interesting details are (33) vertical aligning pins and (37) the sand retain-

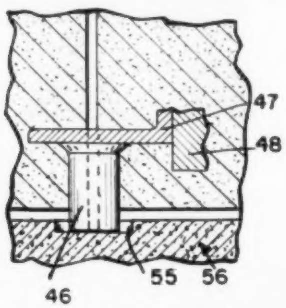


Fig. 5 . . Core section and support.

ing strip placed over the cut-away portion of the flask during ramming.

Figure 5 indicates how the core sections (56) are supported by "ram-up" cores (46) anchored in the sand of the flask at the time of ramming. The ram-up core has a preformed vent passage which contains a wire which

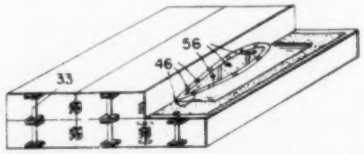


Fig. 6 . . Partially assembled mold.

extends through the sand in the flask. The wires are withdrawn after the flask sections are placed over the main core, leaving vent passages through the ram-up core and the mold.

Figure 6 shows a mold complete except for the last cope section.

Pat. No. 2,827,678 *issued March* 25, 1958 *to Raymond H. Osbrink.*

obituaries

Fred J. Boenecker of St. Louis Dies

Fred J. Boenecker, district representative, A. C. F. Industries, Inc., St. Louis, and Membership Chairman of the St. Louis Chapter, died Sept. 6.

Boenecker had been active for many years in the St. Louis Chapter having served as Chapter Chairman, Vice-Chairman, Publicity Chairman, and was serving his second year as

Fred J. Boenecker

Membership Chairman. He was also Program Chairman of the 1955 Missouri Valley Regional Foundry Conference.

Boenecker was also active in the affairs of other technical societies including the American Society for Metals.

He was born and educated in Mexico and became associated with the National Bearing Div., American Brake Shoe Co., St. Louis in 1927, working in the export and engineering departments. In 1940 he joined Bronze Alloys Co., St. Louis, as a sales engineer and later joined A. C. F. Industries, Inc.

Edmund D. Brack, Sr., 74, consultant, Ajax Metal Div., H. Kramer & Co., Philadelphia, died July 30. He was associated with the company for more than 50 years, and held a membership in the AFS Philadelphia Chapter.

Daniel J. Jones, manager, sales and service, New Jersey Silica Sand Co., Millville, N. J., died Aug. 15. He accepted employment with the com-

pany in 1944 after having taught science in Millville High School. Jones was a member and director, AFS Metropolitan Chapter. At the time of his death, he was serving on the AFS Committee 8-J, Physical Properties of Iron Foundry Molding Materials at Elevated Temperatures.

Kenneth Cooke Brownell, 55, chairman of the board, American Smelting & Refining Co., New York, died Aug. 4. He joined the company in 1927, and was elected president in 1949 and board chairman in 1957. Brownell was also director, Revere Copper & Brass Inc., New York.

Herbert C. Geittman, Jr., sales representative, Climax Molybdenum Co., Div., American Metal Climax, Inc., New York, died recently. He had been with the company since 1955.

Hugh Pope, assistant manager, Eastern Malleable Iron Co., Naugatuck, Conn., died Aug. 8. He was a member, AFS Connecticut Chapter.

W. A. Hallberg, vice-president, Universal Camshaft Co., Muskegon, Mich., died Sept. 5. He held a membership in the AFS Western Michigan Chapter.

C. Franklin, supervisor, Melting Dept., Campbell, Wyant & Cannon Foundry Co., Muskegon, Mich., died recently. He was a member, AFS Western Michigan Chapter.

Now There's an Idea . .

Marble practice in a foundry. The men who will do the pouring of molten metal at Link Belt Company's new foundry in Indianapolis

are using ordinary glass marbles to get the "feel" of new equipment. The spheres simulate the action of molten metal, giving operators the practiced touch needed to pour metal for quality castings.

pouring off the heat

thank you, sir!

■ I have just had the opportunity of seeing a copy of your July issue and the article "Saving Capital."

The manner in which you have written and illustrated the article shows a good deal of imagination and is one of the best presentations I have seen in a trade magazine.

LT. GEN. CHARLES B. STONE, III (Ret)
Chairman of the Board
U. S. Leasing Corp.
San Francisco

come, come to the fair

■ Looking through the registration for the International Congress to be held in Brussels-Liege, I note that very few have been entered from your country.

Your participation in the last International Congress organized in Brussels in 1951 included such a large and brilliant delegation that we were expecting for this year a large number of foundrymen from the States, especially when considering that the Atlantic crossing has been so much improved since 1951. We are consequently somewhat disappointed to see that our hopes were not justified.

I would have liked to have been present at your convention last May; this would have given me the opportunity to personally invite American foundrymen to attend the International. Unfortunately, this was not possible and I have to content myself in submitting by correspondence some arguments which may convince members of AFS to participate in our next International Congress.

Even though business affairs are somewhat more difficult presently, are not leaders of the American foundry industry people looking coldly towards the future and knowing pertinently that better years will follow?

Their presence at our Congress will constitute an official demonstration of an optimistic attitude towards general business and world conditions for all our friends in Europe who may feel somewhat abandoned.

I can assure you that from the technical viewpoint, the papers which have been received are of the highest value and that exchanges

of opinions will not fail to be of interest. Simultaneous translation of the presentation of reports will entirely solve language problems.

I am indeed sorry not to be in a position to present these arguments orally; but although a written invitation is not as warm as a verbal one, please feel assured that our welcome will be in keeping with you in large number with us from Sept. 29 to Oct. 3.

ROBERT DOAT
Association Technique de Fonderie de Belgique
Brussels

a final salvo

"Co-Insurance – 80% of What?" an article on fire insurance by Kenyon D. Love drew some heated replies which were published in the May issue. One reply was from E. I. Morris, Morris Agency, South Orange, N. J. The following is a reply from the author, Mr. Love, to Mr. Morris.

■ The sentence on the basis of a total loss taken out of context and used by Mr. Morris perhaps needs to have more said about it. The discussion concerned a partial loss and the general idea is that if you do not keep your insurance up to at least 80 per cent of the value to be appraised as it was just before the loss, then the company would want to pay a percentage of the loss.

If you carried only fifty per cent, the company would pay only half the partial loss. If you had a total loss the company would have to pay the full amount of the insurance in those states enjoying the legislation requiring it as in the Old Land Mark case in Ohio: Queen Insurance Co. v. Leslie 47 OS 409. It was held that "The statute in Ohio requires the insurer to pay the policyholder the full sum written in the policy, in case the loss is total . . . any provision in a policy for an appraisement or arbitration of the amount of any loss is rendered inoperative . . ."

There are other cases, but the point is that there is no use buying a potential law suit. Either have an agreed upon value, or insist on straight insurance. In cases where the appraised value is much higher than the price you would have to pay for similar facilities today, buy straight insurance.

You don't have to be an expert to use good common sense. I did not advise anyone that I was an insurance expert, and I don't believe it was mentioned by MODERN CASTINGS, either.

KENYON D. LOVE
Colonial Foundry Co.
Louisville, Ohio

New Nemco Foundry

■ Pouring the first aluminum castings in the NEMCO Foundry this summer marked the completion of another step in the expansion program of Nelson Electric Mfg. Co., Tulsa., Okla.

The Oklahoma manufacturing company recently moved into its new 100,000 sq ft plant and office building. The foundry building, located in the downtown industrial district, was rebuilt and enlarged year before last, following a disastrous fire.

Within the past several months, during a recession period in which many

Aluminum for the first castings in NEMCO Foundry's new non-ferrous metals section is poured by Bob Sullivan, foreman.

businesses reduced the scope of their operations, the NEMCO Foundry added a non-ferrous metals section to their casting facilities. Nelson management, looking forward to a predicted boom in the industrial electrical market, took advantage of the adjustment period to prepare for the enlarged market. Booming new industries such as guided missiles are requiring more and more aluminum castings. The demand for lighter and more compact equipment is continually increasing.

The new facilities for pouring non-ferrous metals are housed in a building adjacent to the NEMCO gray iron foundry.

Brass and bronze as well as aluminum will be cast. Three new gas-fired furnaces are employed together with a "continuous pour" production line. Two of the furnaces have 80-lb capacity and the third can melt 300 lb. A new compressor, storage tank and blower system feeds fuel to the furnaces. The CO_2 core and molding process which has provided better finish and closer tolerance on cast iron castings will also be used for casting non-ferrous metals.

NEMCO Foundry has been casting gray-iron explosion-proof enclosures for its parent company, Nelson Electric Mfg. Co., since 1946. Even the largest electrical enclosures used by Nelson can now be cast in aluminum. In addition the foundry does general jobbing work, producing castings ranging from 2 ounces to 7000 lb for industries throughout a region covering several states.

Emmett Hines is foundry manager. Robert B. Sullican—section foreman.

product report . . .

Hot shakeout sand

. . . 350-500 F, does no harm to heat-resistant rubber conveyor belt reinforced with glass fabric. The Solarflex belt, manufactured by B. F. Goodrich Industrial Products Co., Akron, Ohio,

was installed two years ago at Texas Foundries, Inc., Lufkin, Texas. Officials state the belt has already lasted seven times longer than belts formerly used, and is expected to give good service for another two years. Company engineers estimate glass fabric belt has already saved $3500 in belt replacement costs. In addition, the belt has eliminated down-time losses which previously cost 2-1/2 tons of production every time a belt required replacement. It travels 80 ft per min and carries 20 tons an hr of hot shakeout sand.

For Manufacturer's Information Circle No. 944, Page 7-8

Occupational dermatitis

. . . was relieved for all but four of 320 workers suffering from skin eruptions by use of Lixoil, a liquid hand cleanser made by Lixoil Laboratories, Boston. Dr. F. C. Combes, M.D., reports results of this survey in *New York Physician and American Medicine*. He states the cleanser is effective not only in treating but in preventing oil dermatitis and folliculitis. New product was tested against 50 other products involving use of fluorescent cutting-oils, and "has been found the sole detergent removing all fluorescent material from the skin."

For Manufacturer's Information Circle No. 945, Page 7-8

1000-mile range missile launched with aid of 115,000-lb rocket boost uses several 'impossible' castings.

WE CAST THE IMPOSSIBLE . . .

light metal castings with 0.050-in. wall thickness

R. H. Osbrink / *Owner*
R. H. Osbrink Manufacturing Co. Los Angeles, Calif.

On more than one occasion, our competitors have implied that what we do is impossible. We don't believe it, and neither do our customers. But perhaps you will when I state that we:

■ Are using more or less conventional metal patterns and green sand molds in the production of aluminum and magnesium castings with wall thicknesses down to 0.050 in., as-cast tolerances of ± 0.0050 in., and 100 rms or better microfinishes.

■ Consider it good design practice to specify 1/64-in. minimum fillet radii and maximum draft angles of 1 degree.

■ Can produce intricate thin-walled magnesium castings with lengths over 189 in. and widths over 129 in. without a great loss of precision due to shrinkage.

■ Have saved time, weight, and money for our customers by producing very large castings for usage in place of built-up sheet metal assemblies.

Tricks of the Trade

Of course, we have our gimmicks. Some of our molds, for example, are made with synthetic binders and are "green" only in the sense that they don't have to be baked before they are used.

However, much of what is called the "Osbrink process" is a matter of practical experience, common sense know-how, and attention to small details that many foundrymen have failed to consider. For instance, *we have discovered that large unwieldy fillets on castings merely induce shrinkage inequalities and—contrary to popular belief—do not make junctions stronger.*

Excessive draft should also be avoided because it tends to induce structural weakness due to uneven shrinkage.

Regarding such things as dimensional precision and ultra-thin walls, we share the view of most foundrymen that too much quality means too much expense. But we probably differ widely in our interpretation of the expression "too much."

As a rule, customers are not advised to specify 0.0050 in. tolerances where 0.020 in. or 0.010 in. will be adequate. On the other hand, very close tolerances are desirable where the cost of extensive machine work can be saved in the course of a long production run; undesirable where quantity requirements are so small that castings can be machine finished for less than the added cost of close-tolerance patterns.

Thin-Walled Castings

The answer to the question of whether thin-walled castings are structurally reliable depends a lot, of course, on methods used in designing and producing the parts. In our case, static tests have shown that such castings can have an extreme minimum strength factor of about 160 per cent of design load and that the general minimum strength factor is approximately 190 per cent. Further, there have been instances when static strength was much more than twice the design load factor and fatigue tests have indicated that parts usually have double their design life expectancy.

Accordingly, designers can attain much greater weight savings in our castings by specifying higher strength allowables and correspondingly fewer sections—thus taking advantage of the continuity which permits integrally cast structures to have reduced cross-sectional areas of internal bracing.

Following are some of the more interesting examples of the large thin-walled castings we have successfully produced for our customers in the aircraft and missile fields:

"Impossible" castings destined for high-flying service in Jupiter C, BoMarc and Regulus II missiles.

a) *Outboard wing panel for the Regulus I missile*: With its 69 in. leading edge and 76 in. between its leading and trailing edges, this component had an area of about 28 sq ft. Minimum skin thickness was 0.20 in. inboard and tapered to 0.130 in. outboard. Between the skins were integrally cast beams and stiffening ribs with thicknesses comparable to those of the skin, and an integral wingfold hinge. The casting was made from AZ-63-A T-2 magnesium, and had an as-cast finish equivalent to a 125 rms machined finish. It weighed 163.3 lb, or 65.2 lb less than a corresponding built-up assembly; and it saved about 460 assembly hours, more than 48 hours of paperwork issuing time, and the cost of an estimated 2000 fasteners.

b) *Air intake duct*: This was about 22 in. long, 18 in. wide, and 24 in. high; required rib and duct walls that were 0.10 in. thick. It was made by casting ZK-51-A, a zirconium-magnesium alloy, and saved at least half of the cost of a built-up sheet metal counterpart.

c) *Airborne dip sonar reel*: This was 24 in. high, 20 in. wide, and 20 in. deep; comprised a frame, reel, and end housing. It required walls and ribs that were 0.10 in. thick, and a 0.250 in. thick base. Cast from magnesium, it weighed 13 lb less than a previously used assembly.

d) *Gun blast tube*: This had a thickness averaging about 1.250 in.; was made by casting aluminum with the thought that hard anodizing would allow it to replace a relatively heavy stainless steel part. A periphery skin step was cast to fit the contour of the plane, so that no machining would be required prior to installation. (Tests, incidentally, have since shown that the aluminum casting satisfactorily withstands firing shock and fume corrosion.)

Design Advice

In order to make intricate castings with maximal precision and economy, it is often necessary to help customers with their design problems. Recommendations naturally vary, but we usually find that the following points deserve utmost emphasis:

1) Minimize costs by showing on each casting drawing the widest limits of acceptability.

2) Use a central locating point for dimensioning, checking and machining in order to eliminate misunderstandings and costly confusion.

3) Use offset ribs or webs whenever possible in order to lessen the possibility of flaws and deformations due to shrinkage.

4) Apply close tolerances to external surfaces, not across parting lines or in cored areas if this is avoidable.

5) Eliminate the need for expensive pattern changes by employing development tolerances, when practical, and indicate the widest possible dimensional variation from piece to piece.

6) Use a maximum piece part or casting weight, rather than close tolerances on wall thicknesses, for weight control—showing an absolute minimum dimension for structural adequacy—if possible.

7) Specify heat treatments only where strength requirements cannot otherwise be met, and minimize the probable need for costly straightening due to distortion.

Pattern Requirements

Most of our patterns are made by firms that have demonstrated ability to meet exacting requirements. As one of our suppliers recently put it:

"The patterns we make for Osbrink are practically the same as those for other customers, the only important difference being the care with which they are made. In other words, closer dimensions are specified and the company is willing to pay for better work."

Our equipment setup from flask to core box has been functionally engineered to expedite production with a minimum chance for human error. Special care is taken to have all dimensions in close relationship to one another cast entirely in either the cope or the drag side of each mold.

Identifying recesses on the parting lines of core boxes indicate out-of-tolerance boxes when they are obliterated by strike-off. All equipment for precision castings—including patterns, core boxes, and special jigs or fixtures—are painted red to remind workers that they should receive careful handling.

Precision Molding

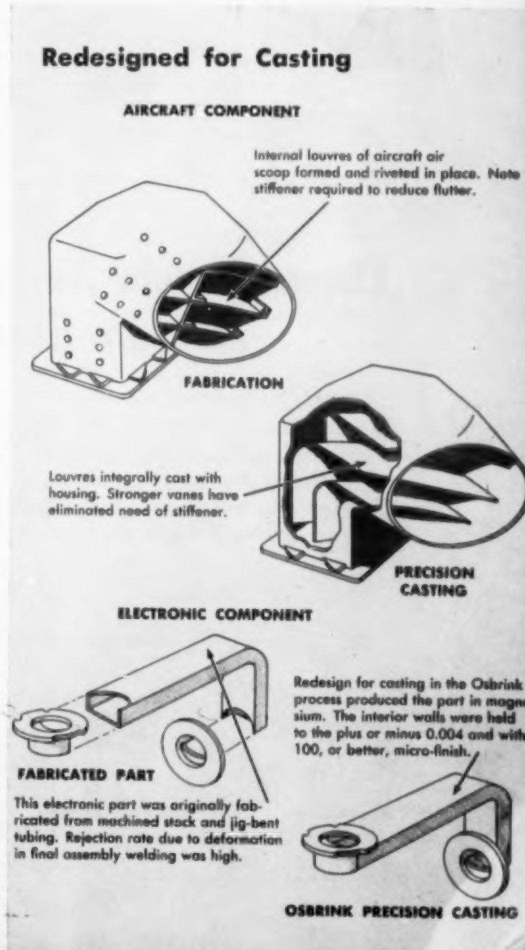
The flasks used are specially designed truss structures which give minimum deflection when fully rammed, yet have relatively little weight. They are carefully matched to patterns and boards in order to preserve specified tolerances when molds are finally assembled.

Aside from binding media, mold and core sands are more or less standard materials with additives like borax to prevent burning and other undesirable phenomena. Where aluminum must be cast, sand mixtures are used with either natural or synthetic binders—depending on quality requirements. But for magnesium, nothing is used but mixes consisting of synthetic binders.

As previously noted, molds are never baked. However, cores are baked and we were among the first to use dielectric heating equipment to get such work done in a hurry without a sacrifice of quality. All cores are given a careful visual inspection, and critical cores are checked with special fixtures.

Use of special locating tools assure the proper placement of cores for precision castings. Internal surfaces with 100 microinch finishes have been obtained where such quality was mandatory.

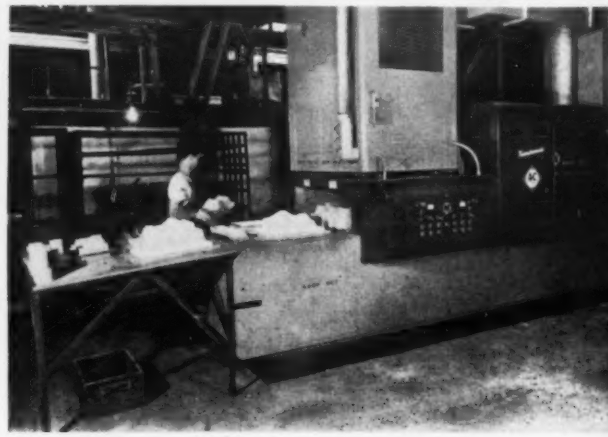
In some cases, molds and cores are finished with carbon-producing



The casting poured from this sand mold will have as-cast tolerances of 0.0050 in.

Castings produced with these green sand molds will replace sheet metal assemblies.

Dielectric core oven speeds core baking without sacrificing the required quality.



Chance Vought Aircraft Gets Real Economy from Impossible Castings

■ Chance Vought Aircraft Inc., Dallas, Texas, is one of the Osbrink customers that has realized savings in manufacturing costs by replacing sheet metal assemblies with thin-walled light metal castings.

Manufacturing complexity of build-up assembly vs. assembled castings for two Chance Vought aircraft components is compared in the following:

Part: **Speed Brake for F7U-3 Cutlass**

	Built-up Assembly	Cast Assembly
Weight	35.55 lb	30.48 lb
Fasteners	750	8
Paper work	324 pieces	78 pieces
	21.1 hours issuing time	4 hours issuing time
Details	54	13
Assembly time	64 hours	2.5 hours

Part: **Outer Panel for Regulus Missile**

	Built-up Assembly	Cast Assembly
Weight	228.5 lb	163.3 lb
Fasteners	2053	minor
Paper work	750 pieces	6 pieces
	48 hours issuing time	30 minutes issuing time
Details	125	5
Assembly time	470 hours	11 hours
Area	28.3 sq ft	28.3 sq ft

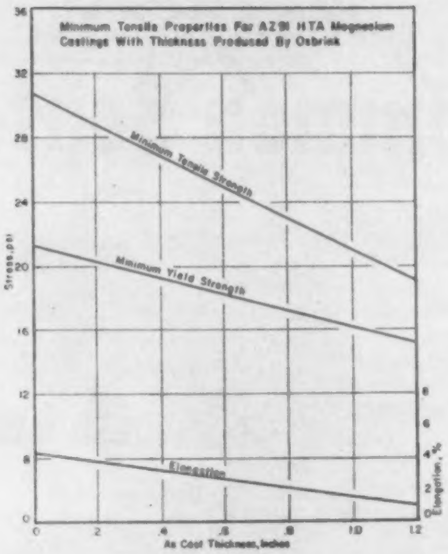
S. K. Hodgson inspects assembly of thin-wall magnesium castings used in Chance Vought missile.

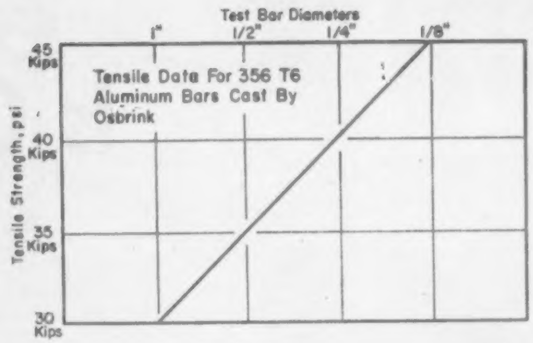
What Makes The "Impossible" Possible?

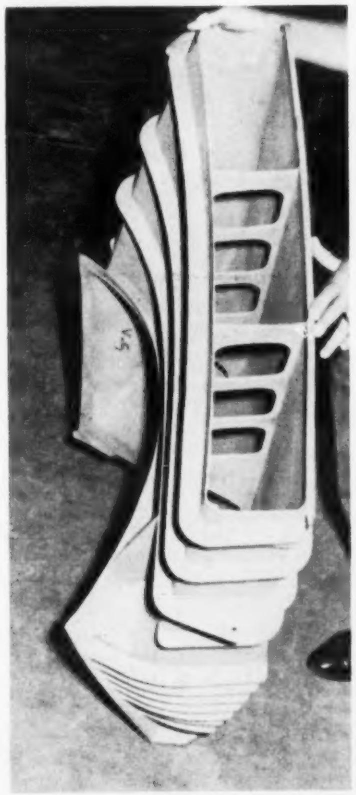
■ Raymond H. Osbrink, author of this article, has patented some of the techniques and equipment used to produce the thin-wall light metal castings he has described here.

Illustrations and information extracted from the patent may be found in the Patent Review, page 17, of this issue.

■ To obtain single additional copies of this article, circle A, Reader Service card, page 7-8.







Navy's supersonic F8U Crusader built by Chance Vought uses this magnesium thin-wall casting.

S. K. Hodgson, staff engineer for Chance Vought reports that one of the most interesting Chance Vought castings applications is an assembly of seven magnesium castings for the Regulus II missile. This assembly is shown on page 24. The large scoop is AZ-63ACS, 0.25 in. thick. All other castings in the assembly are AZ-91-T6, 0.20 in. thick.

Osbrink Mfg. Co. made this casting for Navy F8U jet aircraft and all other parts shown in this section.

flames. Sometimes hard-baked tapered-ring cores are placed in risers and rammed up in the molds. Closefitting tapered plugs are inserted in the cores to seal out metal. When molten metal reaches the plugs they are quickly removed—allowing the metal to fill the risers. Purpose of this is to build up momentary back pressure in mold aiding thin sections of the mold to fill properly.

Quality Control

Melting procedures in general conform with the recommendations of the major producers of aluminum and magnesium alloys. Crucibles of minimum size are always used to assure maximal pouring facility and close temperature control.

Test bars are not made at each pouring, but at intervals—one being produced each time a test slug is made for chemical analysis, or about 20 times daily.

Castings are inspected before gates and runners are removed, during cleanup operations, and after heat treating when required. All reliable types of modern inspection equipment are used, as necessary, to maintain customers' quality standards.

Castings are heat treated in seven high-velocity-air electric furnaces and two low-temperature ovens for aging aluminum.

Micrographs of test bars have repeatedly indicated that our methods tend to reduce the coarseness of metal grain structure with each reduction in diameter or cross-sectional thickness. Results of this improvement in grain are reflected by the following typical data for 356 T6 aluminum bars:

PHYSICAL PROPERTIES

	Bar A	Bar B	Bar C
Actual size (diameter)	1.008	0.509	0.249
Yield Point (actual load in lb)	20,600	5,800	1,550
Yield Point (psi)	25,814	28,501	31,827
Tensile Strength (actual load in lb)	24,300	7,200	1,960
Tensile Strength (psi)	30,451	35,380	40,246
Elongation in 2"	0.04	0.06	0.11
Elongation per cent	2.00	3.00	5.5

WORK SIMPLIFICATION is Organized Common Sense

Here is a plan which encourages workers to join management in halting expensive waste of time and effort

Edgar F. Pierce / *Work Simplification Engineer*
Lynchburg Foundry Co.
Lynchburg, Va.

WORK SIMPLIFICATION is the organized use of common sense to eliminate waste of time, effort and material. The greatest obstacle to simplifying work is not usually technological difficulties but rather arises from the mental attitude of persons who feel they are already using the best possible methods.

Today our best methods and industrial engineers are failing in methods improvement—not because of the technological aspects of a job, but because workers are not willing to accept changes. The workers can hardly be blamed however in view of being subjected to many changes in which they cannot participate or even foresee. Further, many of the changes deprive them of those things which give meaning and significance to their work.

What It Is

For these reasons, many companies are turning toward Work Simplification, an organized program of improvement developed some twenty years ago by Allan H. Mogensen. Using the principles of motion economy and a philosophy based upon good human relations he developed it into a program whereby all the members of an organization might participate.

Work Simplification, as defined by Mogensen, is "the organized use of common sense to find easier and better ways of doing work". The steam engine, plow, spinning wheel, and a young boy cutting across a field between his school and home are examples of common sense ideas put to work and indicates Work Simplification is not new.

Unfortunately, there are too many people who at first glance interpret the term Work Simplification as meaning: speed up, work harder, big company profits, no fair share for me, and work yourself out of a job. Work Simplification is none of these but instead it is a long range, continuous, carefully organized program with the consultative approach, which requires two things:

- *First, the belief that employees have ideas that are worthwhile,*
- *Second, the humility to consult such employees about their ideas.*

The Approach

Why, then is this job so difficult? A rational approach suggests that there are three ways of getting results through people. The first technique has been used for a very long time and is called the "tell them" approach. Everyone is probably familiar with the dictatorial manager who rules his subordinates with an iron fist; who never bothers to explain "why" and who has his mind made up regardless of what others may suggest.

The second technique is the "sell them" approach. Within the last few years, efforts have been made to sell people on the need for increasing productivity and far better results are being obtained than by the "tell them" approach. Also, enterprises are doing a much better job of explaining time study, wage incentives, job evaluation, etc., and are finding that it pays off.

However, management feels the best results are obtained when they use the third technique, "consult them." This approach is well illustrated by experiments conducted at Western Electric Co. in 1924.

There, researchers discovered something far more important than hours or wages or physical conditions; something which increased output no matter what was done about physical conditions. By consulting with a group of girls assembling telephone relays, they were able to boost output to an all time high. This "thing" which increased output was not in the production end of the factory but in the human end. It was an attitude, the way the girls felt about their work and their group. By asking their help and cooperation, the investigation made the girls feel important. Their whole attitude changed from that of separate cogs in a machine to that of a congenial group trying to help the company solve a problem. They found stability, a place they belonged and a purpose they could clearly see.

Five Steps

Our basic problem in the plant is the elimination of waste—waste of time, energy and material. An organized program of Work Simplification provides a five step pattern for improving your foundry operations. These five steps are:

1. Select a job to improve: Those to look for are bottleneck jobs that require too much time, high cost jobs, and jobs requiring chasing around for materials and tools.

2. Get the facts: This step is quite often overlooked. There are many ulcers developing today because foundry managers are required to make decisions without all the facts or with vague information. If a process is written in sufficient detail, in its existing sequence, and is clear, then, and only then, can management successfully think about it. In the Work Simplification program, three charts are employed to assist in breaking down a job. These charts are: (1) Flow Process Chart, which emphasizes distance, (2) Multiple Activity Chart, which emphasizes time, and (3) Operator Chart, which emphasizes individual motions.

These charts help obtain the facts which may bring about a workable solution.

3. Challenge the details: Here management asks the questions: Can we eliminate the operation? Can we combine? Can we change the sequence? What is its purpose? Why is it necessary? Where should it be done? When should it be done? How should it be done? When these questions have been applied to each detail of a job, we are ready for the next step.

4. Develop the better method:

In order to develop the better method an attempt must be made to eliminate every non-productive motion as far as possible. The employees are not asked to speed-up, but instead to work smarter-not harder. Management realizes work performed in a hurry will result in waste because it is a speeding up of all parts of a job, both necessary and unnecessary.

Regardless of how the better method is devised, whether it is by an individual, group, or a brainstorming session, the idea is worthless until it is implemented.

5. Installing the improvement: It must be remembered that the "one best way" is not really so unless the worker performing the job thinks that it is. The human problem to be considered in putting the new method to work is equally as important as the technical problem itself. It must also be remembered that it is human nature for individuals to resist those things which they don't understand and to resent criticism. Unless management can sell the idea to the worker, the improvement so earnestly worked out on paper may never be fully accepted.

Lynchburg Program

With these things in mind, an example of what has been done to secure results in a Work Simplification program would be appropriate. The following account represents the efforts of Lynchburg Foundry Co., Lynchburg Va.

First, management, from president to foreman, was given approximately twenty hours of training in the philosophy; tools and techniques of Work Simplification in order to get not only an understanding, but an appreciation and full support of the program. This effort was made in view of the belief that unless an industrial concern acquires complete support from its management groups, its Work Simplification program is doomed to failure. Further, a training program was initiated for the hourly workers which encompassed regular classroom work and project assignments requiring group participation. The latter was designed to build confidence and gain valuable experience in applying the tools and techniques discussed in the classroom.

An outsider, after learning of these procedures, might ask the following questions: What happens when the people complete their training? How do you keep them sufficiently interested to continue applying what they have learned? What benefits do the people derive from the program?

What has been done is to set up a Proposal for Improvement Plan to provide for the collection and impartial evaluation of ideas, to insure that acceptable ideas are promptly installed, and to give recognition to the originator of each idea.

Recognition, which is synonymous with incentive, can be provided in many ways. Lynchburg Foundry, like many other firms, provides cash awards to the hourly employees but try to administer it in such a way that the money does not assume greater importance than the idea itself. We also give recognition in our magazine, in bulletins and in personal letters.

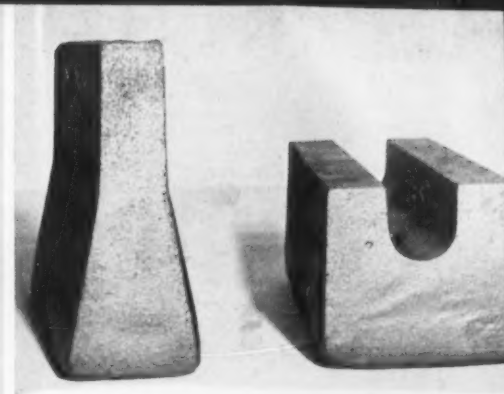
Benefits

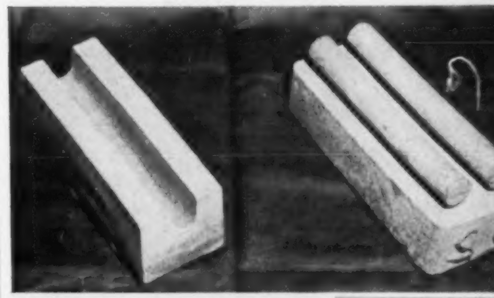
As for the benefits the company receives, they are divided into tangible and intangible ones. It is the belief that as the program grows older, the greatest benefits derived are of an intangible nature—higher employee morale, less complaints and grievances, and, in general, an improved attitude toward the company and the job. The tangible benefits come from direct savings of labor and material. Every year we are receiving and installing ideas which average $15,000 net annual savings. This might seem extremely high but other companies report even higher annual savings.

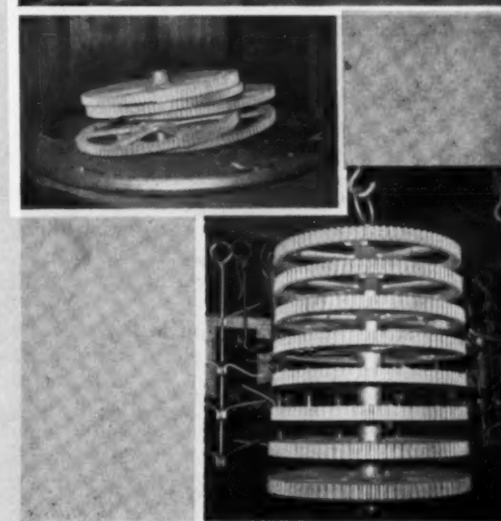
In conclusion, it is safe to state that wherever there are people performing jobs, there is a place for Work Simplification. This is true regardless of how large or small the plant, how automated it becomes, or what type business it is. As competition becomes keener, all concerns will need to rely on the thinking ability of everyone in the organization. "The greatest thinking will come from the people who have the most brains, but the greatest power will come from all the people working together as a team."

■ To obtain single additional copies of this article, circle B, Reader Service card, page 7-8.

Classic Examples of Work Simplification







#1 When Lynchburg Foundry first started producing ductile iron, it was found necessary to use a test bar similar to that used for testing steel to obtain a sound test specimen entirely free of centerline shrinkage.

The use of a keel block, top picture, for test purposes was expensive and laboratory results were delayed by the excessive time needed to remove the legs from the body of the block.

A supervisor of the laboratory recognized this problem, and, after a study of the facts, submitted his idea through the Proposal For Improvement Plan. He proposed a modified keel block which would permit both legs to be knocked off with a heavy hammer blow. This modification is shown in the second picture.

Due to the complexity of the problem, it was necessary to engage the services of personnel in other departments: the Work Simplification Department, Gating and Risering Department, Pattern, Core and Sand Departments.

When the experimental tests were compared between the standard keel block and modified keel block the results showed similar physical properties. However; there were still some improvements to be made and through the cooperation of all concerned a second modification of the block was prepared for evaluation. See third picture.

Approval was then given for the use of the modified keel block in all cases "except where specifications called for ASTM, 1 inch keel blocks or other specific test specimens."

#2 The two combined pictures show a method for blasting castings on a table blast was altered by development of special hook which permits the castings to be blasted in a cabinet blast. The example of work simplification also resulted in considerable savings.

CONTROLLING C H₂ N O IN STEEL MELTING

How to make better castings by using modern melting practices to control these gaseous elements

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Electro Metallurgical Co., Div.
Union Carbide Corp.
Cleveland

The modern-day steelmaking foundryman is faced with a continual dilemma of juggling the carbon, oxygen, hydrogen, and nitrogen content so his final casting has the optimum properties. The evasive gaseous elements play perpetual hop-scotch with the slag and metal chemistry. This article is aimed primarily at setting forth the best melting practices for controlling these four important elements.

Let us now assume that the best use of existing equipment, or the proper choice in the selection of new melting units has been made. The next step is to examine the complex chemistry of the steelmaking process. The proper selection of raw materials and a melt of about 50 to 60 points above tapping carbon is assumed.

CARBON-OXYGEN REACTION—Regardless of the process, acid or basic, arc or fuel fired, the primary steelmaking reaction is the oxidation and removal of carbon as carbon monoxide —$\underline{C} + \underline{O} = CO$. This is the carbon boil which provides stirring for slag-metal reactions, equalizes bath temperature and helps arrive at lower hydrogen and nitrogen by its flushing action. The speed of carbon drop depends on the rate of oxygen supply, the amount of carbon present, the rate of temperature input, and possibly the degree of bottom roughness. The rate of oxygen supply can be greatly improved by blowing either with tuyeres or the introduction of an oxygen lance. Rate of supply from the slag depends on slag composition; e.g., the highly basic slags tend to release oxygen more rapidly than the acid slags.

Since the boil flushes out some hydrogen and nitrogen, now is a good time to dwell briefly these elements in steelmaking.

HYDROGEN—Hydrogen dissolved in liquid carbon steel in amounts more than 0.00075 per cent or 7.5 parts per million exceeds the solubility on solidification and can cause porous or wild ingots and castings. At higher alloy contents more hydrogen can be tolerated without porosity. Lower amounts of hydrogen in the solid steels can cause flakes and generally lowered ductility. Annealing or aging treatments are used to remove hydrogen in low alloy steels.

Recent work by Epstein, Walsh and King[3] has emphasized the following points in controlling hydrogen contents in liquid steel.

(1) A vigorous boil should be maintained to flush the hydrogen content of the bath to a low value.

(2) After deoxidation heats should be tapped as soon as possible.

(3) Good ladle, runner and mold practice are necessary to prevent hydrogen pick-up during the tapping and teeming of killed steels.

(4) Additions made after the completion of the boil should not have been stored under wet conditions.

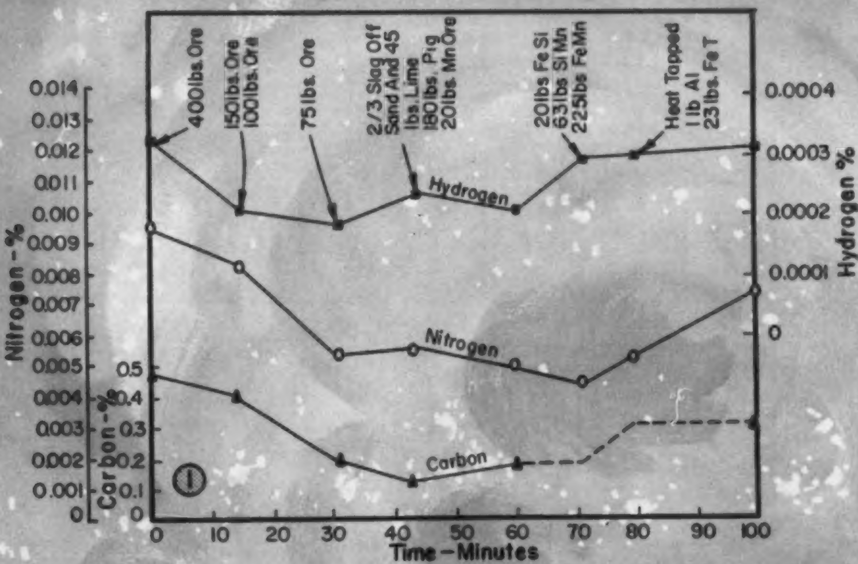
The average hydrogen content table for low alloy steels[4] for various steelmaking processes is shown on page 30. With more recent knowledge, the basic electric steel can be made with hydrogen contents as low as 3 ppm without vacuum casting.

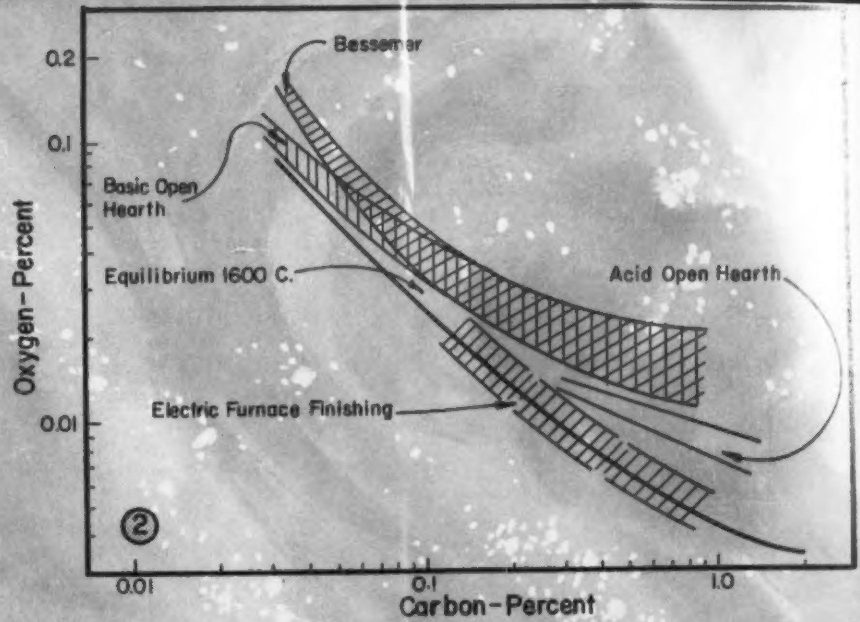
NITROGEN—In most cases good furnace practice uses a strong carbon boil. The nitrogen content is then well below the solubility level on solidification. Therefore, nitrogen alone is not considered a serious offender in affecting porosity.

The average nitrogen content[4] table for low alloy steels for various steelmaking processes is shown on page 31. Most low alloy steels can tolerate 0.017 per cent nitrogen at solidification without porosity.

In ordinary cast steels low nitrogen is desirable. A combination of high nitrogen with heavy aluminum deoxidation may produce aluminum nitrides in the grain boundaries and thus produce rock candy fracture with attending lowered ductility.

In the austenitic grades of stainless steel for castings, wide use is made of nitrogen for grain refinement, increased strength at elevated temperatures and as a substitute for nickel in forming austenite. In plain chromium steel castings moderate use has been made of nitrogen for grain refinement, particularly in the steels of high chromium content. The use of this element in the low-chromium—12 per cent chromium steels must be approached with caution as these compositions have limited solubil-



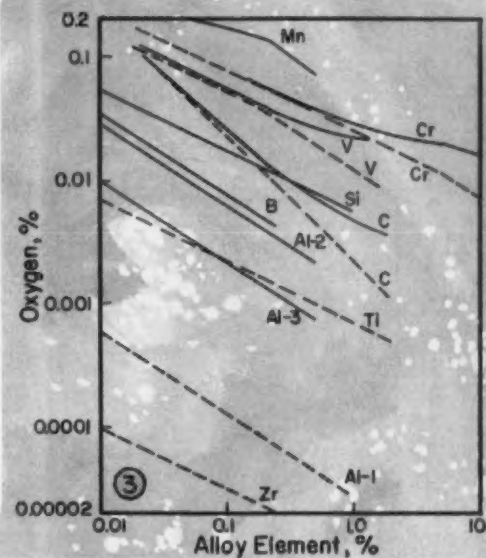


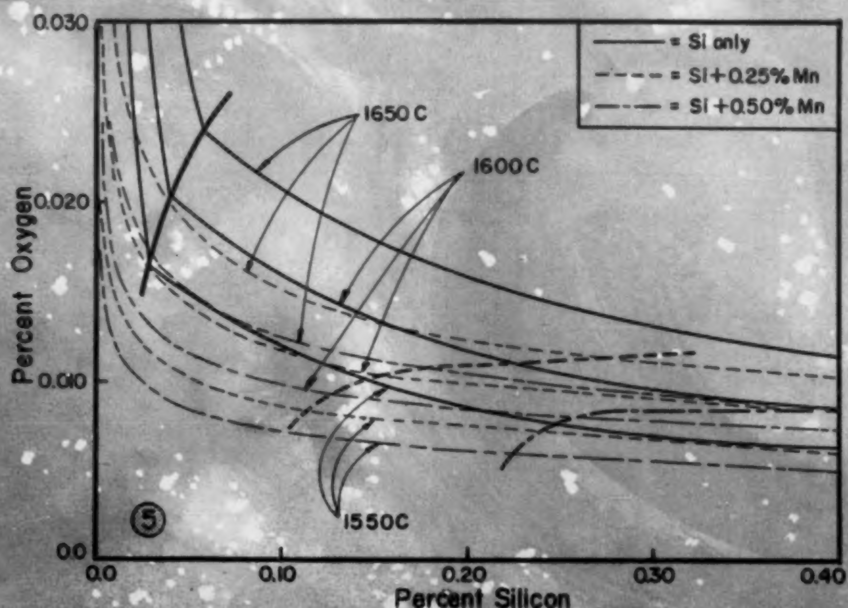
ity for nitrogen. When green sand molds are used, porosity from combined nitrogen and hydrogen may easily occur.

Figure 1[5] shows the level of hydrogen and nitrogen during the working of a six ton acid ore heat. Note the tendency for both of these elements to increase in the metal after deoxidation.

PINHOLE POROSITY—The subsurface porosity which sometimes develops in green sand castings is an example of gas pick-up after the steel has been poured. Pinholes are usually not found when high permeability dry sands are used or when the steel is thoroughly deoxidized with aluminum[6]. The mechanism suggested by Savage and Taylor[7] seems most likely. The reaction of liquid steel with the water in the sand dissolves both oxygen and hydrogen. While hydrogen tends to diffuse toward the center of the section, oxygen accumulates at the surface. Unless sufficient deoxidizer is present the carbon-oxygen reaction begins and gas bubbles or pinholes form below the surface. The hydrogen in the steel near the mold interface then diffuses into these bubbles.

OXYGEN—Since carbon is removed by oxidation it follows that the oxygen must be dissolved in the bath. The level of oxygen in the molten bath is mainly controlled by the amount of carbon present. A schematic curve from Carney[8], (Fig. 2) shows the oxygen levels for varying carbon contents in the different steelmaking processes. Note the acid open hearth (these values apply to the acid electric) and basic electric under reducing slags tend to be close to the equilibrium value while the more oxidizing processes tend to have somewhat higher oxy-





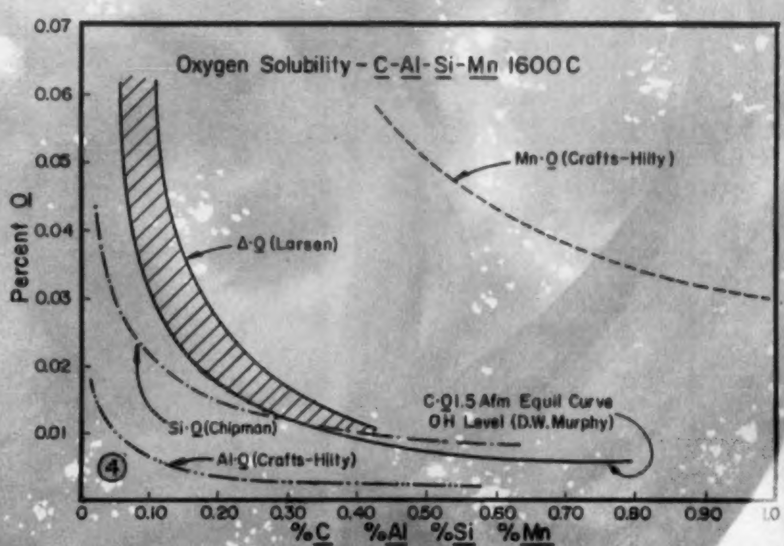


Figure 1

HYDROGEN CONTENT OF COMMERCIAL LOW ALLOY STEELS

	Weight % Average H_2 — Parts Per Million
ACID OPEN HEARTH	3.5
ACID ELECTRIC ARC	2.0
BASIC OPEN HEARTH	5.9
BASIC ELECTRIC ARC	4.9
BASIC BESSEMER	6.5

gen contents. At true equilibrium the carbon-oxygen reaction is at a steady state and the boil is stopped.

DEOXIDATION — Deoxidation is simply the stopping of the carbon-oxygen reaction so sound steel free from blowholes can be safely poured into a mold. This can be done by shutting off the supply of oxygen; e.g., by slagging off and adding a very low oxygen reducing slag to the basic electric furnace. It is generally accomplished under oxidizing slags by adding an element or combination of elements known as deoxidizers which will either combine with the oxygen and remove it in the form of an oxide or oxides, or reduce the effectiveness of oxygen in the bath.

Tennenbaum[9] shows that deoxidation or blocking lowers the oxygen in the basic open hearth to the level encountered in the basic electric furnace under reducing slags. This is the equilibrium value where the carbon oxygen reaction cannot proceed.

Some foundries use a single slag practice in the basic electric. Here the heat is lightly blocked (deoxidized) to quiet the boil and the oxygen is not lowered to the equilibrium value. In general castings are tapped under more oxidizing conditions than ingots.

making[10]. This shows that zirconium and aluminum are the strongest and manganese and chromium the weakest deoxidizers when acting alone.

In Fig. 4 the effect of carbon aluminum, manganese and silicon on oxygen solubility is shown. The carbon-oxygen curve is from plant data presented by D. W. Murphy[11]. You may note the silicon curve is above the carbon curve at carbon values over 0.30 per cent carbon. This explains why it is difficult to stop the carbon reaction with silicon alone at high temperatures and high carbon levels. This figure also shows why manganese acting alone is a weak deoxidizer.

It has been found that combinations of some elements have a stronger deoxidizing effect than when either element is acting alone. Hilty and Crafts[12], have compared silicon plus manganese and aluminum plus manganese to these elements acting alone on oxygen solubility. Aluminum plus silicon is no more effective than aluminum alone. The effect of silicon and manganese acting together to remove oxygen illustrates what Herty, et al,[13] found many years ago as to the value of silicomanganese (combined silicon and manganese alloy) on the removal of oxygen as $MnO\text{-}SiO_2$ inclusions.

Bath temperature also affects the strength of deoxidizers. This can best be illustrated in Fig. 5 from Hilty and Crafts[14]. Here three temperature levels are shown together with three different deoxidation levels in liquid iron. Laboratory data explains a long known melting effect that hot heats do not block tightly.

VARIOUS STEEL MAKING PRACTICES
AVERAGE NITROGEN CONTENTS FOR LOW ALLOYED STEELS

Acid Open Hearth	0.005-0.006
Acid Electric Arc	0.008-0.010
Basic Open Hearth	0.004-0.006
Basic Electric Arc	0.006-0.014
Duplex — Acid Bessemer To Basic Open Hearth	0.007-0.010
Blown Metal and Hot Metal Acid Bessemer	0.014-0.020
Basic Bessemer	0.017
Basic Side Blow Bessemer	0.002-0.006
Pig Irons — Basic Pig	0.002-0.008

Effect of Various Elements on Oxygen

The effect of deoxidizing elements on the oxygen content of liquid iron is shown in Fig. 3, taken from *Basic Openhearth Steel-*

Steel Quality

It has been shown that the final total oxygen content of steel is controlled by the amount of car-

Continued on page 120

1958 TRANSACTIONS PREVIEW

MELTING PRACTICE FOR ALUMINUM CASTING ALLOYS

By

William N. Brammer*

ABSTRACT

This is a practical discussion of today's successfully used melting technique as applied toward the production of the highest-quality aluminum-alloy castings.

The writer covers furnace equipment for melting and holding, metal cleanliness, and temperature control. Common abuses of the melt, their effect and correction are detailed; among these are sludging and fluxing.

Aids to improved casting quality, such as grain refining and sodium modification, are discussed as foundry tools.

This paper reveals nothing new in research or scientific discovery, but is meant to be a guide to the user of aluminum alloys for any casting technique. It will be found to reconfirm the experienced melter's knowledge, supplement the theoretical reading available, and may be helpful as a training guide for all foundry personnel.

The technique of metal melting and handling is vitally important to any foundry operation, and constant control and vigilance are necessary in the preparation of aluminum for casting. This will maximize casting quality while minimizing end product costs.

Aluminum alloys have three inherent characteristics which should be recognized, and if simple precautions against these are taken, the basic pre-requisite for good quality uniform castings has been fulfilled. These characteristics are the tendency of molten aluminum to absorb hydrogen, the ability of aluminum to readily oxidize, and the ease with which aluminum dissolves iron.[1a] It is the purpose of this paper to discuss these scientific facts as they are reflected in everyday melting in the casting plant.

FURNACE MELTING EQUIPMENT

In preparing the melt for casting any one or combination of three different furnace-melting systems may be used, and each has some advantages which are unique.[1b]

One system utilizes the reverberatory furnace wherein melting and metal ladling are performed from the same furnace unit. This can be oil or gas fired, and ingot metal, and/or recycled foundry metal, are charged in one end and ladling wells are provided on another wall of the furnace. The fuel is burned in a firing chamber directly over the metal, and the products of combustion come in direct contact with the molten aluminum.

This is sometimes modified by the installation of a complete baffle floor so that the firing chamber is self-enclosed and all heat input is thus radiated to the molten aluminum bath by conductive fire brick. The sacrifice of furnace efficiency with this baffle reverb is not generally agreed to be offset by appreciably better quality metal. The reverberatory furnaces are generally placed in a line through the production area with pouring stations located at the front ladling well or wells. Ample service space, at the rear of the furnace, should be provided for servicing with metal and for fluxing.

Due to the varying requirements of the different areas within a furnace, that of melting in the rear and holding for pouring in the front, generally pouring temperatures can be held to ± 20 F. These furnaces are usually of about 1,000-4,000 lb capacity and will use two to six burners depending on individual design. The rear of the furnace is opened for cleaning and fluxing, and is sometimes fitted with a dutch-oven arrangement for pre-heating the charge. This pre-heating will increase the efficiency of the furnace in lb of metal melted per hr as much as 10-15 per cent.

When a large volume of metal is required per hr at the pouring station, the reverberatory furnace will be very satisfactory if properly handled and maintained. The refractory lining minimizes iron pickup.

Stationary or Tilting-type Furnace

A stationary or tilting-type furnace using a silicon-carbide crucible can also be used for melting or pouring. These are placed in a melting area properly hooded to permit the escape of exhaust and fluxing gases. Automatic temperature control is not necessary but desirable on breakdown melting furnaces. Furnaces should at least, be equipped with a positive reading temperature pyrometer. This furnace is generally placed in an individual floor pit or surrounded with a charging platform to permit working of the melt. The pouring spout, when tilted, should direct the stream into a transferring ladle from a medium height.

An ideal manufacturing layout will utilize a double-furnace system wherein the aluminum is melted and brought to the pouring temperature in one furnace, cleaned and treated if necessary, and then transferred to a holding furnace at the pouring station. The

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author's company believes this is to be the best setup for both permanent mold and die casting.

Electric Induction Furnace

The third system of melting uses the electric induction furnace. These are equally adaptable to breakdown melting or holding. The original capital investment, however, is sizable. They can be fitted with a receiving tundish, permanently mounted on the shell of the furnace, which will receive the stream from the bull ladle and direct it tangentially down the furnace wall. This minimizes oxide formation in the bath. Plant layout considerations are similar to those for the crucible-type furnace.

The electric induction furnace has been used successfully both as a melter and holding unit and is generally capable of melting 5-7 lb per hr, per kw rating of the furnace. In the opinion of the author's company, it offers two distinct advantages for use with aluminum. First, because of the absence of products of combustion the aluminum can be melted and held with a minimum absorption of hydrogen. Second, due to the intermittent flowing action of the metal in the bath, alloy segregation is practically nil. The investment is greater than for other furnace types, but with proper maintenance, they are practical and make for a much cooler work area due to the minimum of radiated heat. They are very accurate on temperature control, and tolerances of $\pm$ 5 F are common. Depending upon the power cost in an area, they can reflect economical operation. It is customary to start these furnaces by flame preheating and then, an initial charge of molten metal.

The electric furnace, by its basic design, does require constant cleaning of channels. The power should always be turned off when fluxing the electric furnace with a solid-type flux. The same agitation which minimizes alloy segregation will also, under some conditions, cause entrapped oxides within the casting.

With crucible or induction melting and holding there is less chance of gas absorption and oxidation, because the molten metal is never in direct contact with the products of combustion.

HOLDING FURNACE EQUIPMENT

Aluminum holding furnaces varying in design features and holding 400 to 600 lb are the most common. It is mandatory that they be equipped with automatic temperature controls. This will provide metal temperature control of $\pm$ 10 F which is practical for sand, permanent molding, and die casting. These furnaces are generally placed in a position convenient to the pouring station and need not be hooded as only a minimum of fluxing is done at this point.

The burner mounting in this crucible furnace should direct the flame into the retort toward the upper half of the crucible and tangential to the crucible wall. Flame impingement on the crucible not only reduces furnace efficiency, shortens crucible life, but also has a tendency to gas the melt. The inner floor should be tapered toward an easily accessible clean-out or drain door. This will facilitate removal of metal should a pot fracture during operation, and expedite the installation of a new crucible with a minimum of lost production time.

Iron pots have long been used to melt aluminum and provide ideal heat transfer and long life for a moderate cost. However, due to the tendency of molten aluminum to dissolve iron from an iron pot the silicon-carbide-type crucible has gained much popularity. Either type of pot should be regularly scraped clean with a pine board and spray coated with a whiting or china-clay wash. A thoroughly dried coating is necessary to eliminate possible gas pickup in the melt. Using proper maintenance and handling care, a silicon-carbide crucible will give long life with the desirable conditions for clean gas-free metal.[2]

Regardless of the type of melting furnace used, metal may be conveyed by bull ladle from the melting area to the casting station as required. The metal may be added to the holding-furnace bath with a minimum of agitation and disturbance by the use of a pouring basin which can be mounted permanently on the holding furnace shell cover. The pouring basin should be designed to receive the metal from the transfer ladle, allow it to flow at a reduced speed through an orifice constructed to direct the flow of the metal tangentially to the furnace or crucible wall. The reduced size of the stream with positive direction will reduce the agitation of the bath, thereby holding to a minimum the amount of oxidation and gas absorption.

METAL CLEANLINESS

The first requirement for quality castings is to use the best grade of smelter ingot. Cleanliness is then very essential in handling and melting aluminum. Particular attention must be given to positive temperature control and to the avoidance of contamination, if quality castings are to be produced.

All tools such as skimmers, ladles, flux chargers and the like, used in the bath, as well as crucible or pot inner surfaces should be coated with a protective wash. It is easy to keep a large container of whitewash or similar slurry handy, and after pre-heating tools to dip coat them with the material. Occasionally, all tools should be shot or sand blasted and a new coating applied.

Iron or silicon carbide pots should be entirely cleaned out once each day during a three-shift operation, or at the termination of pouring on the one- or two-shift plan. It is good to scrape the walls down with a pine board and remove all oxides and scum from the walls of the crucible and then apply a new, medium heavy coating of protective wash. By using the board as a scraper, the resultant charring will not fracture the glazed surface of a silicon-carbide crucible. A simple machine cleaning gun will be adequate for this spraying operation as it delivers a large volume of material with a concentrated spray pattern and is inexpensive. All tools and crucibles should be dried thoroughly before use.

Ingot metal should be stored inside so as to be protected from the weather. This minimizes the formation of hydrated oxide coating which does not decompose until temperatures approaching the melting point are reached. This hydrated oxide will result in gassy metal if not removed. If outside storage is unavoidable, the ingot should be wire brushed, or oxide residue removed in some other convenient man-

ner, and then preheated to drive off most of the occluded moisture. Preheating temperatures of 800 F to 850 F for 15 to 30 min will be sufficient in all but the most severe cases. In making up the charge for the melting furnace it is desirable to use a mixture of ingot and foundry scrap keeping a ratio of 60 per cent ingot to 40 per cent scrap. This reference to "scrap" means rejected castings, gates, risers, trim, flash, etc. The initial charge in the furnace should be of small gates, risers, flash, etc., so as to most completely fill the heel of the pot with molten metal quickly, then ingot material may be added.

SLUDGING

Sludging is one of the common ills of the casting operation, particularly where pouring temperatures lower than 1300 F are used.[3] Sludging results when the heavier elements in the alloy (Fe, Mn, and Cr combined with Si and Al) are never brought to a temperature hot enough to effect solution. In all cases, regardless of the alloy used, the melt should be brought up to at least 1300 F and stirred in the breakdown melting operation even though a lower pouring temperature is being used. This will help assure that all the alloying constituents are in solution and reduce the possibility of segregation.

The aluminum-silicon-iron-manganese compounds are the most serious offenders, and at 1200 F they are actually only partially in solution. Consequently, they segregate to the bottom of the crucible in the form of a heavy sludge which also changes the original composition of the alloy. Improved technique in the melting room would involve raising the melt to 1300 F, fluxing properly, milding stirring the bath, and skimming off the dross and oxide. It is not meant to imply that a pouring temperature of less than 1275 F is undesirable. Quite to the contrary, lower temperatures are often very desirable, but it is a good practice to bring all metal up to at least the higher temperature, effect solution of all alloying consituents, and then drop back to the lower pouring temperature.

Thus, segregation may be held to a minimum. Solid ingot or scrap should never be charged into the holding furnace, as the chilling action induced promotes the segregation of the heavy high-melting constituents. The often repeated metaphor of "sugar in coffee" need not be repeated but is applicable[4] (Fig. 1).

TEMPERATURE CONTROL

Constant vigilance is needed in the melting area to avoid over heating of the melt, and while it is costly from the standpoint of wasted fuel energy it also has a very pronounced effect on the alloy. Both oxidation and gas absorption are promoted by high temperatures. Temperature recording and indicating equipment may be panel mounted adjacent to the furnace, and should be equipped with a visible or audible signal to indicate when the metal is on the high side of the pouring range (Fig. 2).

Thermocouples are usually suspended in the bath, and are of the chromel-alumel type with a refractory or cast-iron sheath or tube protector. These should be periodically wire brushed clean and coated with a protective wash to insure accurate results and maximum life. Overheating or holding at elevated temperatures for extended periods of time will tend to have three pronounced detrimental effects.[5]

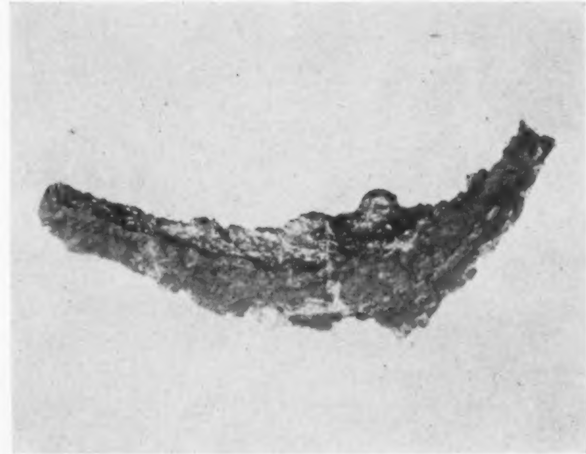

Fig. 1—Heavy element sludge.

First, the higher the temperature the more prone the aluminum is to gas absorption which is extremely troublesome on machined, polished or pressure tight castings. Unsoundness of any kind results in lowering of the mechanical and physical properties of the alloy, particularly the elongation.

Second, elevated temperatures will result in a coarsened grain structure, and can modify any previous refinement or modification of the alloy.[6] This in turn will decrease the machinability, pressure tightness, and foundry castability.

Third, the aluminum will tend to oxidize more rapidly at the higher temperatures, and in some cases, loss of portions of some of the alloying elements can occur. This may result again in lower properties of the alloy, and will increase the melt loss of the foundry.

If it is found necessary in permanent molding, due to mold design, to pour at temperatures in excess of 1350 F, the melt should be held a minimum possible length of time at the pouring temperature.

INVENTORY CONTROL

In some jobbing foundries where many different alloys are used to satisfy individual customer requirements, use of a color code system for alloy identification is highly recommended. Most smelters will

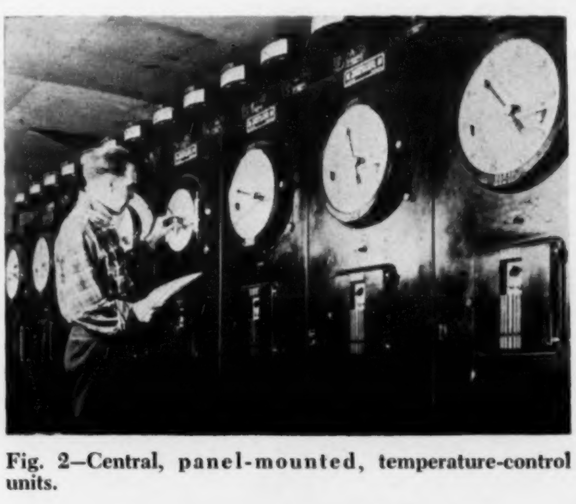

Fig. 2—Central, panel-mounted, temperature-control units.

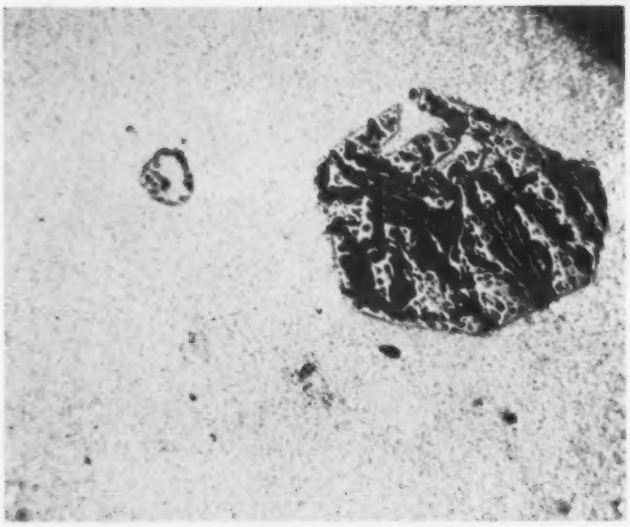

Fig. 3—Piece of hard complex trapped in die-casting. 40×.

stripe each ingot end with water paint to the Aluminum Association Code for easy foundry distinction. This color code should be displayed and known throughout the plant. Large color plates should be placed on each furnace to mark the alloy being used therein. The various containers at the cutoff operation should be color coded for positive alloy separation. In short, a color code is simple, positive, easy to use, and very effective.

FLUXING ALUMINUM ALLOYS

Fluxing is a foundry tool that should be used when necessary and is that plus factor of assurance toward the highest quality castings. Theoretically, it is unnecessary, but years of casting experience have demonstrated that it is the best means of obtaining clean metal by preventing excessive oxide formation, removing inclusions and foreign matter, and liberating dissolved hydrogen from the aluminum melt.

Proper fluxes are the secret to cost and quality control in the aluminum foundry. The melting of all metals requires thoughtful operation and control. In the foundry operation there are various sources of contaminants that can be harmful to the finished casting.

What are these items and what are their sources?

Metal Oxides. Aluminum oxides have a specific gravity close to that of the aluminum alloys, and thus they have a tendency to remain suspended in the molten bath. The normal source of these oxides is from remelted gates, risers, rejects, and excessive agitation of the melt. Removal of these oxides can be made by the proper use of degassing or cleaning flux (Figs. 3 and 4).

Gas Porosity. This is generally evidenced by a dispersion of fine pinhole cavities throughout the casting and considerably more evident around heavy sections. The gas, hydrogen, can be picked up from over-heated melts, undried crucibles, foundry returns, condensed moisture on the charge, steam from products of combustion of the fuel, and even humid atmospheres. Economical degassing of the melt can be made with degassing flux (Fig. 5).

Foreign Material. Foundry sand, dirt and oil on occasion are associated with foundry returns, and are often charged back into the furnace for remelting even when otherwise good practice is observed. Clean metal may be assured by proper fluxing.

Fluxes are of two general classes, solid or gaseous. The solid-type fluxes are of two different types depending upon the manner in which they react in the bath.

Let us look first at the solid fluxes.

Cleaning flux—for special cleansing and mild degassing. This flux is used primarily to produce a clean molten metal bath that is free of oxides and foreign material that may be suspended in the melt.

Approximately, 4 oz. of flux per 100 lb of metal is used. For maximum benefit, after the melt reaches about 1250 F, the flux is added to the surface and thoroughly stirred in. The appearance of small yellow flames shows the progress of the reaction, and when the dross becomes of dry powdery consistency, the reaction is complete. In a matter of a few min, the accumulated dross may be removed from the melt with a perforated skimmer.

Degassing Flux—is noted for its strong degassing action and may be used with any aluminum alloy. It is the practical method for controlling hydrogen in aluminum. Approximately 4 oz. of flux per 100 lb of metal is recommended. It may be wrapped in aluminum foil and placed in an inverted perforated cup and plunged to the bottom of the melt. For best results it should be added when the melt has reached 1200 F. The chemical and mechanical action of the evolved gas will pick up the dissolved hydrogen gas and help clean the melt of suspended oxides.

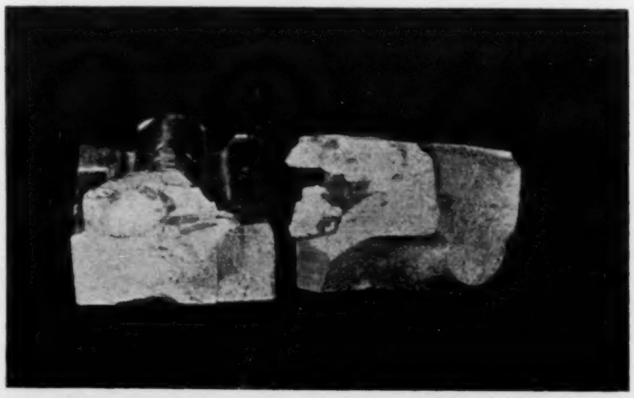

Fig. 4—Die-casting section showing oxide inclusion.

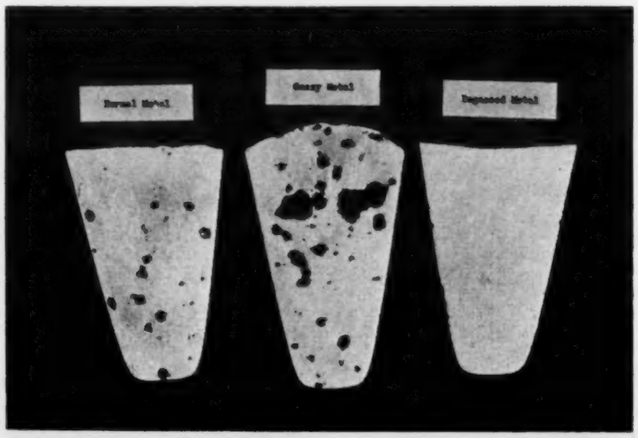

Fig. 5—Vacuum test samples illustrating gas content.

Utility Flux—for cleansing and mild degassing. This flux is used to produce a clean molten metal bath that is free of oxides and foreign material that may be suspended in the melt. The flux is best added at about 1250 F-1300 F and worked in with a perforated skimmer. Additions are made until the foreign material clings together and the mass has become a cherry red color. It is then removed. An excess of flux will result in a liquid mass which is difficult to remove effectively.

Cleaning Flux—for magnesium-aluminum alloys is a balanced composition containing more than 1 per cent magnesium. This flux is prepared for aluminum-magnesium-type alloys because of the necessity for maintaining a balanced chemical composition and preventing loss of magnesium. It is added in the same quantity and in the same manner as the standard treating flux. It will give maximum cleansing and will also act as a mild degassing flux.

Gaseous fluxes for aluminum may be nitrogen or chlorine gas. It is important for aluminum fluxing to obtain "oil-pumped" rather than "water-pumped" gas for obvious reasons. The gas is introduced to a well-hooded furnace by a carbon tube equipped with a diffuser head, attached to the gas bottle or reservoir. The diffuser head is very important to obtain many fine bubbles of gas rather than several large ones, since a greater surface area of the gas will eliminate more hydrogen.

The gas should always be turned on before introducing the tube into the bath. This avoids any frozen metal in the tube. A rate of flow which will mildly ripple the surface of the bath is good. Severe agitation will decrease the efficiency of gas fluxing. Generally, five min of gas flow for quantities of less than 500 lb, and slightly longer for larger furnaces, will be adequate. This is the most efficient means of cleaning and degassing aluminum alloys.

Chlorine degassing must consider the importance of the magnesium content of the alloy, as at elevated temperatures reduction of magnesium can change the composition (Fig. 6).

GRAIN REFINING

In permanent molding, where irregular temperature gradients occur within the mold, large grain structures can often be noticed in the casting. This denotes that this area of the casting has not been chilled sufficiently in the mold, or that progressive solidification has not been obtained. In the case of thin-sectioned castings, elevated temperatures necessary for complete fill can cause coarse grain size.

In most of these cases, grain refining of the melt will prove helpful toward producing an internally sound casting. It will aid the foundrymen to improve pressure tightness, mechanical properties, machinability, and if close dimensional tolerances are being held, that is, piston-pinhole inside-diameter dimensions, sizes may be held more consistently. The addition of grain refining elements must not be considered a cure-all for abusive metal melting practices, but only a tool to be used where required.

The grain refining elements may be introduced through hardeners or fluxes and aid in producing fine equi-axed grains in the alloy.[8] Because they lose

HOW FLUXING HELPS STRENGTHEN ALUMINUM ALLOYS

Typical Examples of Improvement in Mechanical Properties by the use of Aluminum Flux.

	Degassing Flux	Unfluxed
Heat-treated type—A.S.T.M. SG70A alloy, T.6 Condition.		
Ultimate Tensile strength, psi	33,000	29,000
Yield strength, psi (0.2 per cent offset)	24,000	20,000
Elongation, per cent in 2 in.	3.5	2.5
BHN (500 kg, 10 mm)	70	70
	Cleaning Flux	Unfluxed
Sand-cast Type—A.S.T.M. CS43A alloy.		
Ultimate Tensile strength, psi	25,000	22,000
Yield strength, psi (0.2 per cent offset)	15,000	13,000
Elongation, per cent in 2 in.	2.0	1.5
BHN (500 kg, 10 mm)	60	60
Permanent-Mold type-A.S.T.M. SC64B alloy.		
Ultimate Tensile strength, psi	34,000	26,000
Yield strength, psi (0.2 per cent offset)	19,000	16,000
Elongation, per cent in 2 in.	2.5	1.0
BHN (500 kg, 10 mm)	85	85
Die-Cast Type-A.S.T.M. SC84A alloy.		
Ultimate Tensile strength, psi	46,000	37,000
Yield strength, psi (0.2 per cent offset)	25,000	20,000
Elongation, per cent in 2 in.	3.0	1.5
BHN (500 kg, 10 mm)	80	80
Magnesium-Containing Type-A.S.T.M. ZG32A alloy, sand cast.		
Ultimate Tensile strength, psi	35,000	30,000
Yield strength, psi (0.2 per cent offset)	19,000	16,000
Elongation, per cent in 2 in.	9.0	5.0
BHN (500 kg, 10 mm)	65	65

NOTE: The above properties were obtained from remelted gates, risers, and sprues.

Fig. 6—Comparative table of mechanical properties resulting from fluxed and unfluxed recycled foundry return.

effectiveness somewhat upon metal remelting, they are most effective added at the pouring station.

Titanium, zirconium, and boron are all good grain refining elements, and can be added easily through a grain-refiner flux.

The grain-refining flux is a quality flux which not only cleanses but refines the structure of the casting. An addition of about 4 oz. per 100 lb of metal will grain refine the alloy. This grain refinement will reduce shrinkage and gas porosity, and will also help to prevent dross and cracks, as well as improve the appearance of the casting. This flux is particularly helpful when pouring temperatures must be very high, or when the proportion of previously melted metal is greater than normal. The same effects can be obtained by the use of these elements in alloy form as hardeners.

Holding a melt for extended periods of time, as well as overheating, will tend to diminish the effect of grain refiners and should be avoided. Excessive amounts of grain refiner will effect the mechanical and physical properties unfavorably. Melting-room technique for adding these fluxes should follow the same order as when using solid fluxes for cleaning or degassing as mentioned before (Fig. 7).

MODIFICATION

The use of metallic sodium to modify the grain structure of silicon in aluminum-silicon alloys is a recognized practice for sand and permanent mold casting

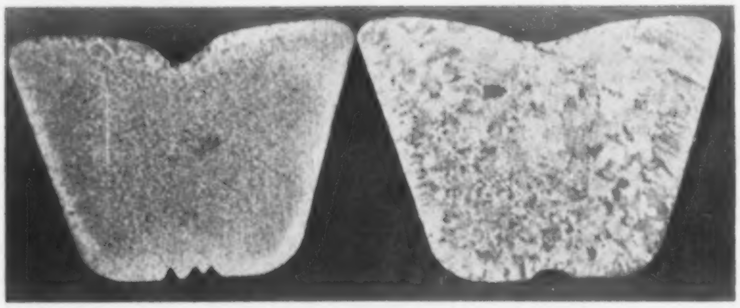

Fig. 7–Etched ingot slices showing effect of grain refining.

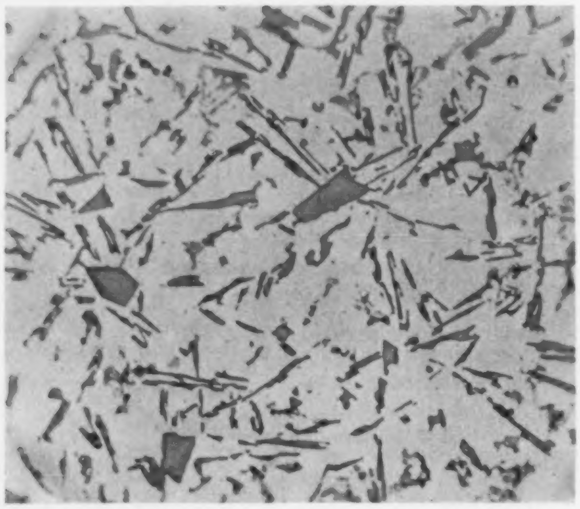

Fig. 8–Eight per cent Si-Al alloy structure, sand cast, unmodified. 250×.

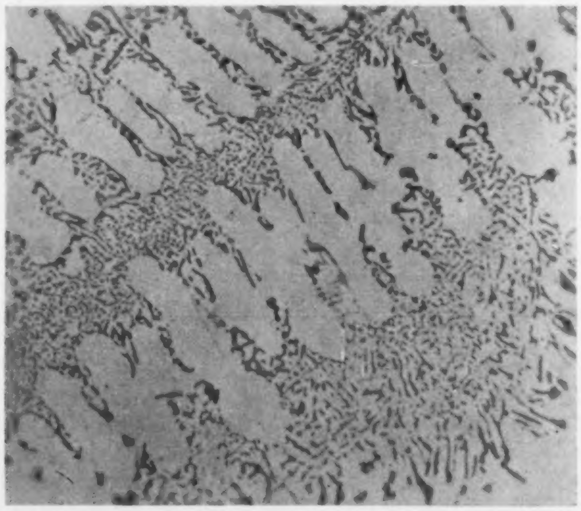

Fig. 9–Eight per cent Si-Al alloy structure, sand cast, Na- modified. 250×.

alloys. A sodium addition of 0.05 per cent maximum will change the normal long silicon needle-like crystals and disperse the silicon more uniformly throughout the alloy in smaller spherical particles.[10] This will not only improve the mechanical properties but also make for improved machining and polishing.

Sodium additions in the foundry should be limited to the minimum necessary to effect modification. Excessive sodium makes for decreased fluidity while decreasing the shrinkage tendency in the mold somewhat. In alloys which are sodium modified, the use of chlorine gas or chloride-type fluxes removes the effect of the sodium and eliminates the modification. Another addition of sodium is then advisable (Figs. 8 and 9).

There is no substitute for good melting technique in a casting operation. Proper maintenance of equipment and tools, the establishment of correct charging and melting procedures, and the intelligent use of fluxing and grain refining methods are essential if highest quality castings are to be produced.

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DUPLEXING PAYS AT AUTOMOTIVE FOUNDRY

By

H. A. Laforet* and F. J. Webbere**

ABSTRACT

Changes in foundry operations related to duplex processing of gray iron at the authors' company have resulted in increased efficiency, lower cost of iron, and improved control. The company foundry has demonstrated that under favorable circumstances the duplexing of cylinder iron can show a net cost advantage if used to its full potential. Duplexing allowed major improvement in cupola practice and metal transfer operations.

Although there is some difference of opinion in the foundry industry today regarding the relative economics to be gained by duplexing gray iron, the authors' company can report convincing success. Beset with complex control problems, one division's foundry resorted to the installation of two 15-ton electric-arc furnaces to obtain a metal reservoir which would assure not only sufficient quantity but more uniform iron at the pouring lines. Tapping operation from the electric furnace into transfer ladles is shown in Fig. 1.

This is a conventional arrangement. The advantages of duplexing were clear cut and greatly outweighed the accompanying limitations. Productivity was increased in the foundry, and the machine shop had fewer complaints. In addition, the cost of iron delivered to the pouring lines was substantially reduced. It should be emphasized, however, that the net gain for any particular foundry must be related to the prevailing circumstances which justify the capital expenditure. There are many gray iron foundry operations where duplexing would not be considered economical.

DUPLEXING BENEFITS

The greatest benefits appeared in the cylinder iron of approximately 180 to 230 BHN. The nominal composition is 3.25 per cent carbon, 2.25 per cent silicon, 0.75 per cent manganese and 0.30 per cent chromium. Prior to the installation of the electric furnaces the division foundry had been experiencing great difficulty in obtaining satisfactory metal quality. A cooperative survey by this division and the company's research staff disclosed several undesirable situations both in the foundry and in the machine shop.

These conditions, although metallurgical in nature, actually stemmed from interruptions in the production rate of castings. Automation in both molding and machining operations had created serious problems for the foundry. As represented in Fig. 2, the machining lines for the cylinder block and cylinder head were fully mechanized with the latest type of tooling and transfer equipment available. The melting department, however, was not modernized to the extent that a uniform grade of iron could be poured at all times.

Fig. 1—Tapping gray iron from 15 ton duplexing furnace.

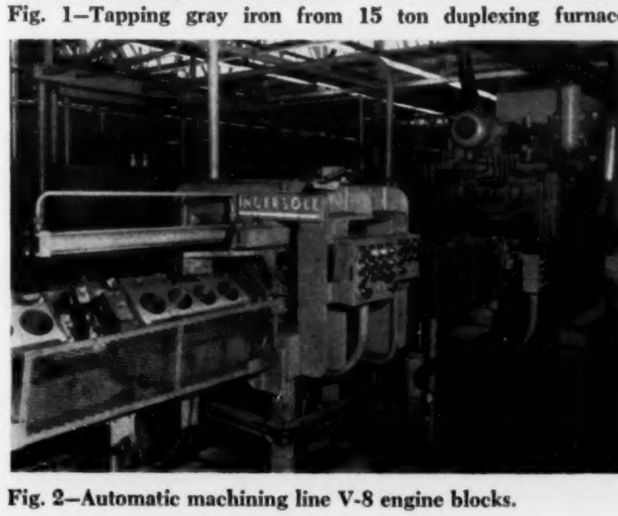

Fig. 2—Automatic machining line V-8 engine blocks.

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For successful operation the highly mechanized machine shop required castings which were more closely controlled for hardness and structure than could be furnished by the foundry. At the same time, the engineering requirements of the iron were increased to meet the higher horsepower trend in engine design. The problem for the foundry was, therefore, much more critical and progressive steps were obviously necessary.

Furthermore, the installation of a new high speed automatic molding line* capable of producing all the plant requirements for cylinder blocks had increased the frequency of maintenance stoppages. This one line was designed to produce 207 cylinder blocks per hr and required upwards of 30 tons of molten iron per hr to maintain a uniform rate of production. Any interruptions of the molding line, due at times to the increased maintenance problem with the new highly mechanized equipment, resulted in an inadequate supply of castings for the machine shop. These irregularities in the molding line output indirectly affected control of the metal at the cupola, adding to the machining difficulties.

When the block line was functioning well, the demand for metal approached the ultimate capacity of the cupolas. When production on the block line was interrupted, the output of at least one cupola had to be drastically and immediately curtailed. This frequent, irregular variation in the melting rate made close chemistry and temperature control impossible and was reflected in decreased efficiency in all parts of the foundry and in the machine shop.

REASON FOR CHANGE

A typical check on one cupola for a 16-hr run revealed as many as 20 interruptions in melting. This situation had far reaching consequences. Total carbon content varied from 3.35 per cent to 3.82 per cent and fell within the preferred range of 3.10 per cent and 3.40 per cent on only one sample during the entire day. Silicon ranged from 2.02 per cent to 2.45 per cent. Chill depth tests were outside of the preferred range for almost half of the day's operation. Spout temperatures ranged from 2660 F to 2785 F. It was impossible to set up proper coke ratios and charge make-up since melting was seldom stabilized.

Along with strong recommendations for improvement in preventative maintenance, charge composition, and control procedure, an intermediate holding station to provide a store for hot iron appeared essential. The obvious advantages of electric arc duplexing, (blending the output from several cupolas, improved temperature control, and opportunity for chemistry adjustment) dictated the installation of the two electric holding furnaces. Some consideration was given to the use of forehearths but space requirements were unfavorable.

The old lay-out at the foundry consisted of 8 back slagging cupolas. Cupolas 1, 3, and 5 were alternated with 2, 4, and 6 to produce cylinder iron. Cupolas 7 and 8 were used on alternate days for soft iron to provide metal for manifolds and housings.

This cupola layout, required an intermittent tapping operation which limited the size of the transfer ladles to about one ton each and complicated the metal handling problem. Larger ladles could not be used without risk of emptying the cupola wells.

The most appropriate solution would allow for 1) blending of the iron to obtain more uniformity in composition and 2) improved temperature control by use of a holding furnace which could add heat to the bath as required. An electric duplexing furnace was, therefore, substituted for cupola No. 3 without disturbing the adjacent cupolas. This resulted in a close but workable fit, the transformer being located directly behind the furnace and under the former charge make-up floor of the replaced cupola.

The remaining cupolas were modified for front slagging and continuous tapping directly into the electric furnace. A second electric furnace was installed adjacent to cupola No. 8 for soft iron. This new arrangement is shown in Fig. 3 with the changes in the metal transfer system represented by dotted lines.

The melting department was now set up to run No. 1 and 2 cupolas alternately with No. 4 and 5 for the production of cylinder iron. Cupolas No. 7 and 8 alternated on soft iron. Cupola No. 6 was left idle. The entire duplexing procedure was worked out and staffed by existing cupola personnel.

The major advantages derived from duplexing of the cylinder iron were: 1) improved composition and temperature control, 2) decreased scrap, 3) decrease in cost of raw materials in the charge, 4) increased productivity, 5) cleaner melting operation, 6) reduction in amount of metal pigged for low temperature, and 7) more uniformity in the metal in castings supplied to the automatic machining lines. The magnitude of these benefits is indicated below.

COMPOSITION CONTROL

The output of two-cylinder iron cupolas are blended continuously in the 15-20 ton bath of the electric furnace. This is the equivalent of 6-8 cupola charges which levels out the irregularities introduced by variations in charge make-up or cupola melting conditions. Figures 4 and 5 illustrate representative operations before and after duplexing was inaugurated.

Before duplexing, total carbon content was deliberately held on the high side in order to avoid the more objectionable consequences resulting from excessively hard iron. Since duplexing, the total carbon content can be controlled at a lower level to take advantage of improved mechanical properties. The effect on silicon is also shown by a maximum devia-

*"Handling Units Speed Foundry Cycle", *Iron Age, Vol. 180,* 23, December 5, 1957, pp. 134-135.

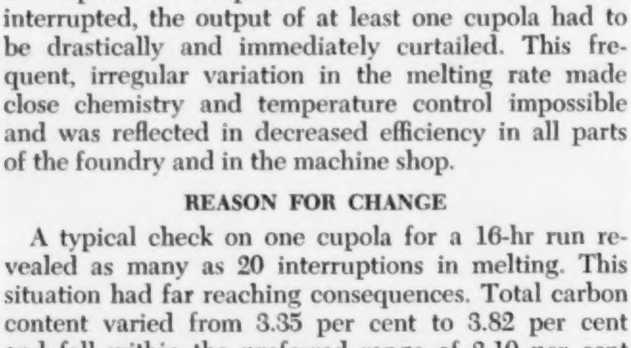

Fig. 3—Layout of melting department showing location of duplexing furnaces and changes in the metal transfer system.

tion of ± 0.10 per cent Si over the entire day in present operation.

CHILL CONTROL

With duplexed iron the total variation in chill shown in Fig. 6 is approximately 1/32-in. for the entire day's operation. It is now standard practice to inoculate with 1-2 lb/ton of graphitizer in each ladle. Previously it was not uncommon to run as high as 15-20 lb/ton of the graphitizer. The fluctuation in chill before duplexing is also shown in Fig. 6. These graphs show data from two different chill tests, but the relative deviation from the preferred range may be used for comparison.

The net effect of this improved control is depicted in Fig. 7 which shows the hardness distribution on production V-8 cylinder blocks from both periods. Hardness values, including measurements on cylinder walls and pan rails, varied from 135 to 229 BHN before installation of duplexing. Rejection of all blocks below 160 BHN was necessary to assure satisfactory field service requirements. The range has now been narrowed to 163 to 212 BHN. Rejection of cylinder blocks because of hardness deviation has been negligible since duplexing was begun.

TEMPERATURE CONTROL

The advantage of an electric holding furnace for temperature control is quite obvious. Not only can uniformly hot iron be delivered to the transfer ladles regardless of delays, but extra temperature can be achieved to compensate for unusual conditions such as the initial heat loss in handling at the start of the first shift. The first iron from the cupolas is now used in castings.

There is no initial period of pigging as was previously customary. All pigging has been eliminated inas-much as cold metal held at the pouring line can be returned to the electric furnace for reheating.

SCRAP REDUCTION

The foundry currently operates at a much lower rejection rate than ever before. Loss of castings chargeable to the melting department due to slag, misruns and off-specification iron is almost negligible.

CHARGE COST

One of the most significant advantages of the duplexing operation which had not been anticipated was satisfactory operation on lower cost materials in the cupola charge. The use of cast iron and steel briquettes was formerly limited to a maximum of 20-25 per cent in the cylinder iron and none in the soft iron. The foundry is currently operating with 20-25 per cent briquetted borings and turnings in the cylinder iron charge, and 10-15 per cent briquettes in the soft iron charge. The difference in charge make-up for cylinder iron is shown in the Table 1.

The straight cupola operation at the foundry had required a premium grade of alloy pig iron. Due to the continuous blending of metal from two cupolas, lump and briquette ferro-alloy additions can now be utilized to the fullest. Reduced cost can often be achieved depending on market prices of scrap and raw materials. Furthermore, electric furnace iron is inherently harder than cupola iron of the same composition, a condition attributed to better solution of

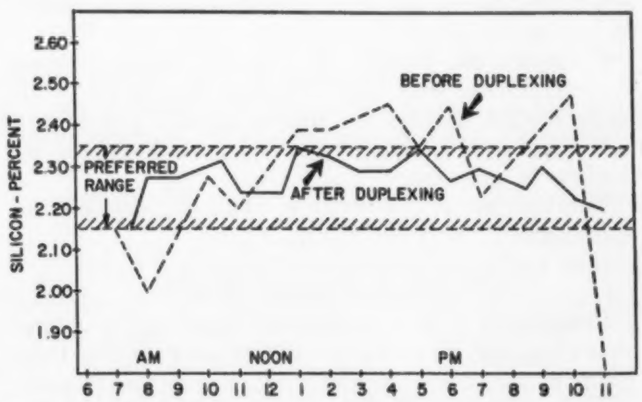

Fig. 5—Variation in silicon analyses for typical day showing improved control with duplex melting of cylinder iron.

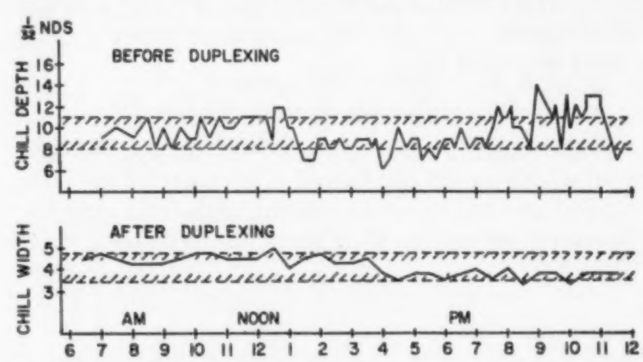

Fig. 6—Variation in chill test for cylinder iron before and after installation of duplexing operation.

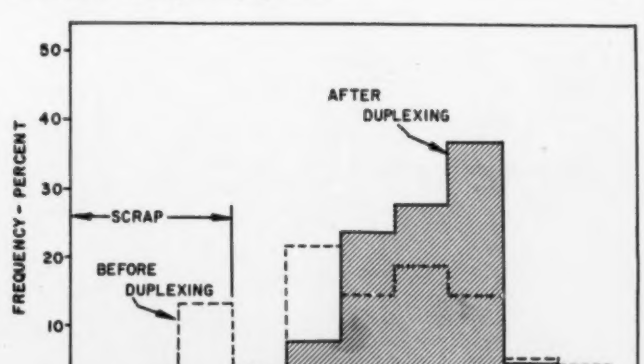

Fig. 7—Distribution of hardness values for V-8 cylinder blocks representing comparable production periods.

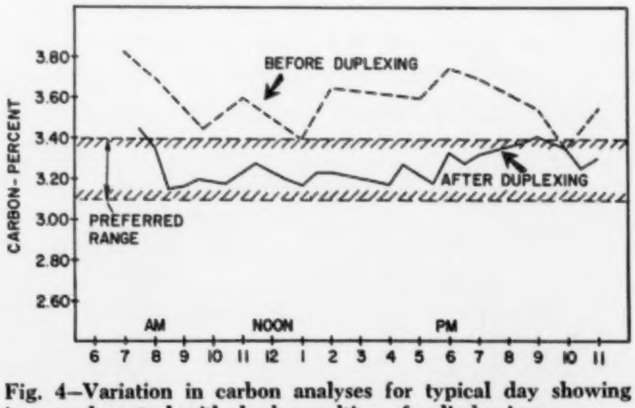

Fig. 4—Variation in carbon analyses for typical day showing improved control with duplex melting of cylinder iron.

TABLE 1 – CHANGE IN CYLINDER IRON CUPOLA CHARGE COMPOSITION PERMITTED BY DUPLEXING PRACTICE

Cylinder Iron Cupola Charge (5000 lb)	Charge Before Duplexing, %	Charge After Duplexing, %
Steel Scrap	14.9	9.0
Steel Briquette	9.9	13.0
CI Briquette	14.9	17.0
CI Scrap	31.7	30.0
Malleable Pig	21.8	29.4
Briquette (Si, Mn, Cr)	–	1.6
Cr, Mn, Si Pig Iron	4.3	–
Silicon Pig (16% Si)	2.5	–
	100.0	100.0
Coke	850 lb	580 lb
Limestone	235 lb	175 lb

the graphite nuclei. Alloy content may, therefore, be reduced to the low side without impairing mechanical properties.

Operating two-cylinder iron cupolas near maximum capacity rather than three cupolas intermittently affords further savings by improving the metal/coke ratio from 5.9/1 to 8.6/1 with an accompanying reduction in limestone.

The net savings in charge materials amounts to approximately $4.00-$4.50/ton of iron.

INCREASED PRODUCTIVITY

Conversion of the cupolas to front slagging, and increasing the capacity of the transfer ladles from 1 ton to 2-1/2 ton capacity, resulted in an increase of approximately 40 per cent in the direct labor productivity of the melting department. This was achieved by continuous tapping into a metal reservoir which could supply the larger transfer ladles without risk of emptying the furnace.

MISCELLANEOUS BENEFITS

Front slagging also eliminated the nuisance of slag wool which previously floated to all parts of the melting and molding areas. Duplexing with front slagging, therefore, proved to be a much cleaner and a more efficient operation. Finally, there was evolved a much improved relationship between the foundry and the machine shop. This is difficult to evaluate in dollars but is of vital importance in improving the foundry product and reducing over-all costs.

DISADVANTAGES OF DUPLEXING

The possible disadvantages of duplex operations should not be over-looked. Heading the list is the absolute dependence of the entire metal flow on one conversion unit. Since all the cylinder iron passes through the one duplexing furnace, any shut down of this unit will stop all the cylinder iron lines. It is expected that ample preventative maintenance and well-timed repair will minimize this possibility.

The only serious problem experienced in the initial operation of the electric furnaces was holding the banks due to the high fusion materials used in repair. The bottom and banks are now repaired with a natural sand which has a lower fusion temperature and will sinter with the residual heat of the furnace.

Refractory costs for the front slagging cupolas were increased over that of the intermittent tap-type cupola primarily because of the maintenance of the troughs and launder. For cylinder iron this increase was only 4.5 per cent. For soft iron the increased refractory cost was approximately 46 per cent. The increase for the cylinder iron would be greater except for the elimination of one cupola made possible by the electric furnace. Two cupolas are now furnishing as much iron as three cupolas did previously.

The over-all increase in operating costs including power, electrodes, refractories, and amortization is in the range of $0.75 to $1.50 per ton of iron tapped. This it more than offset by the $4.00-$4.50 per ton savings in materials charged into the cupola.

The success of the duplexing operation at the foundry may be attributed to the determination to exploit every advantage the electric holding furnace afforded. The over-all package of improved quality, greater productivity, and lower metal costs has been most gratifying.

SALT BATH HEAT TREATMENT VS. QUENCH AND TEMPER

STANDARD AND PEARLITIC MALLEABLE

By

P. W. Green*

ABSTRACT

This paper gives a preliminary coverage of the basic manufacturing methods used in the production of standard and pearlitic grades of malleable iron, a physical property comparison between oil-quench and temper and isothermal salt transformation of standard and pearlitic malleable iron, and a comparison of the microstructures, mechanical properties and hardness values obtained from the two heat treating techniques.

All iron to be used in the production of standard 35018 grade malleable iron and the various grades of pearlitic malleable produced is melted in a conventional batch-type furnace, fired with pulverized coal. The base chemistry of the metal is given in Table 1.

Laboratory weighed packets of 8-mesh medium-carbon ferro-manganese are added to the ladle to give 0.60-0.85 per cent contained manganese in the iron for pearlitic work.

A typical charge is listed in Table 2.

The heat treatment of standard and pearlitic grades of malleable iron is done in 5-ton capacity, electric elevator car-type furnaces. The first stage of both classes is similar in that a high temperature of approximately 1800 F is maintained sufficiently long for massive carbide breakdown. In straight malleable the load is then transferred to another furnace for complete anneal by slow cooling through the critical range. The pearlitic grades, on completion of the first stage, are air-quenched to give a fine pearlitic matrix, a spheroidizing treatment just below the critical completes the second stage.

The standard malleable iron, produced from the base composition and heat treatment mentioned above, develops physical properties covered in A.S.T.M. 35018 grade. Typical properties obtained in the pearlitic grades produced with a constant heat-treating cycle and variable manganese levels are shown in Fig. 1.

Both of the above mentioned end product materials can be further heat treated similar to steel.

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TABLE 1 – BASIC CHEMISTRY OF MALLEABLE AND PEARLITIC MALLEABLE IRON

Chemical Ingredient	Percentage
Carbon	2.25 – 2.35
Silicon	1.00 – 1.05
Manganese	0.35 – 0.40
Phosphorus	0.09 – 0.11
Sulfur	0.09 – 0.12
Chromium	0.015, Max.

TABLE 2 – TYPICAL CHARGE, MALLEABLE AND PEARLITIC MALLEABLE IRON

Ingredient	Percentage
Sprue	50 – 55
Malleable Scrap	3 – 5
Steel Rail	10 – 12
Pig Iron	29 – 32

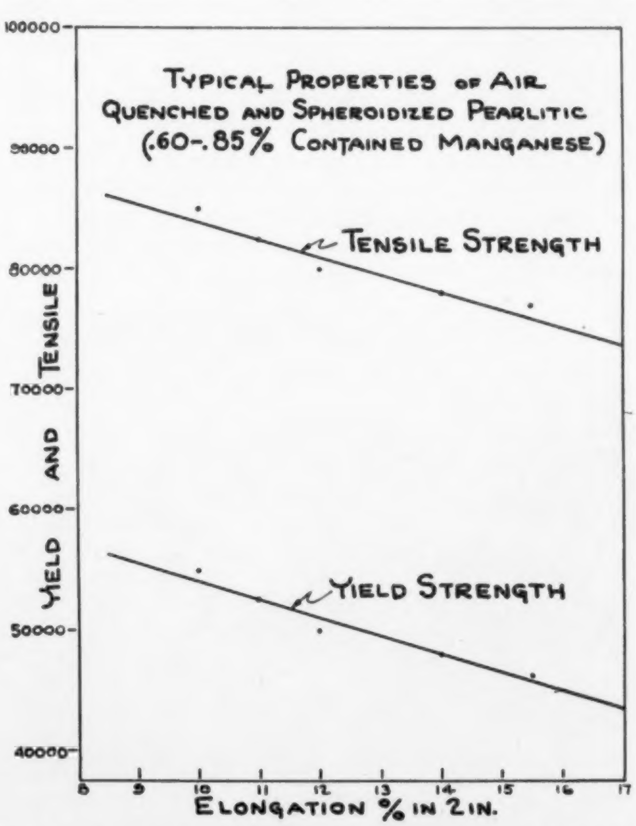

Fig. 1–Typical properties obtained in the pearlitic grades of iron produced with a constant heat-treating cycle and variable manganese levels.

Fig. 2—Solution and tempering furnaces along with agitated oil tank used in the quench and temper study.

QUENCH AND TEMPER TREATMENT

Standard and pearlitic malleable tensile test bars were used in this phase of the study in order to determine the various mechanical properties obtainable. Brinell hardness readings were obtained following the quench and temper study by cutting wafers from the bars and brinelling the cut surface. These wafers were also used for the photo-micrographic work. A carbon block was used in the solution furnace to retard oxidation.

Groups of bars from both classes of malleable were solution treated at 1600 F in a standard heat-treating furnace. After holding for 1 hr they were quenched in agitated oil to room temperature.

The quenched bars were then tempered at various sub-critical temperatures for 2 hr.

Figure 2 shows the type of equipment used while Fig. 3 shows the microstructure obtained as quenched in oil. The as-quenched Brinell hardness of the standard malleable ran 520 while the pearlitic material (0.80 per cent contained manganese) ran 530 Brinell.

The results obtained on the quenched bars after tempering at various temperatures are shown in Fig. 4.

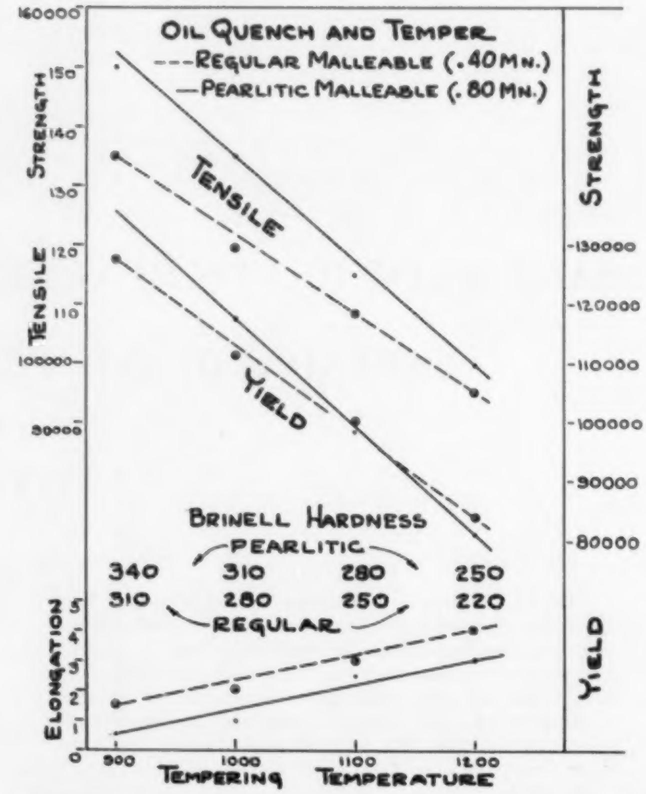

Fig. 4—Typical mechanical properties of regular and pearlitic malleable iron oil quenched and tempered at various temperatures.

With tempering time remaining constant (at 2 hr), the hardness drops as the tempering temperature increases in both the regular and pearlitic malleable grades.

When a comparison of hardness values to tensile and yield strength is made, the regular and pearlitic grades are similar.

Also the elongation figures are identical when standard and pearlitic irons are tempered to the same hardness value.

As shown in Fig. 5, there is a constant increase in carbide precipitation and size as the tempering

Fig. 3—Martensitic structure obtained from the oil quench. Nital etch. 100×.

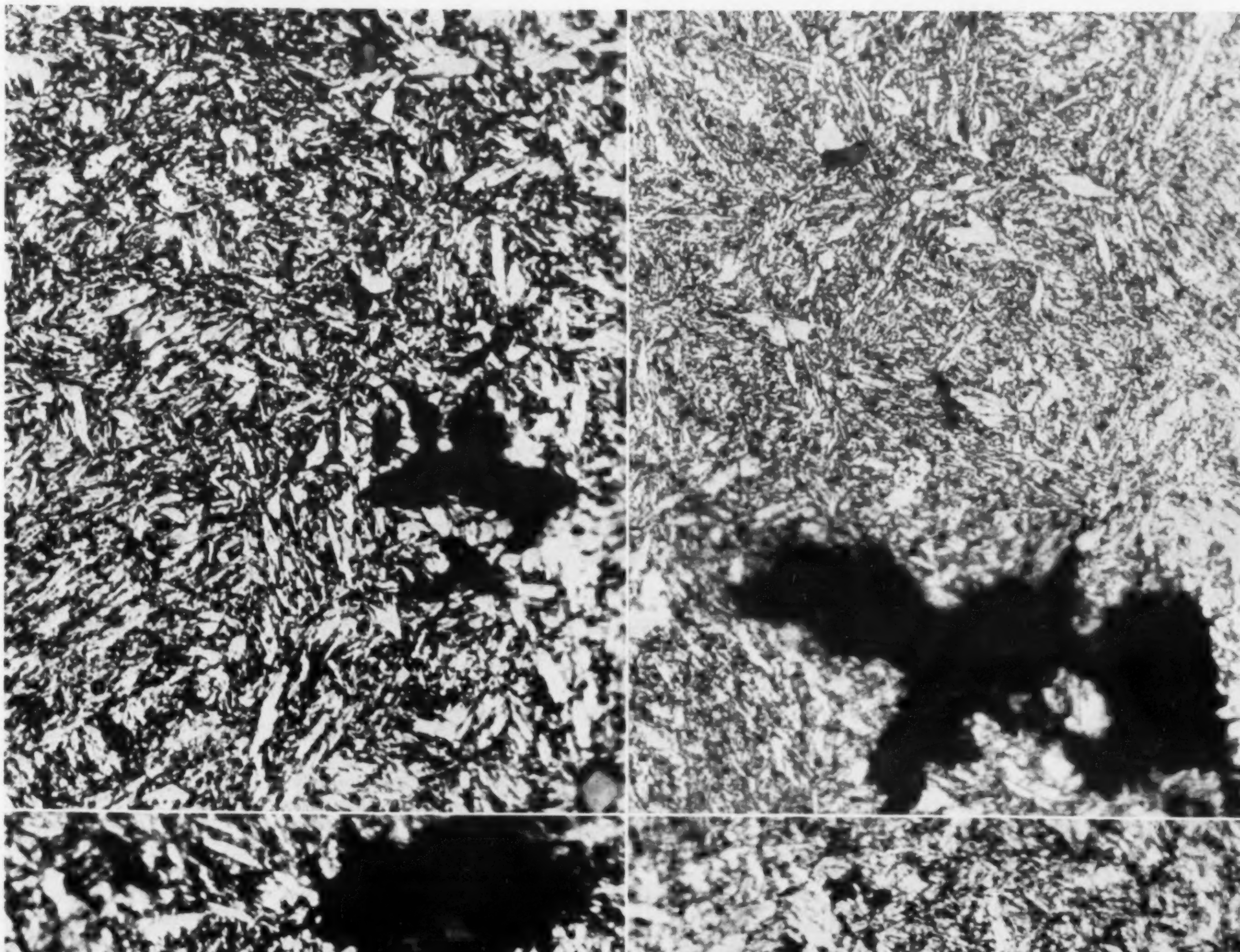

Fig. 5—Photo-micrographs showing structures produced by oil quench and temper of regular malleable at 900 F, (upper left), at 1100 F (upper right) and pearlitic malleable at 900 F, (lower left), at 1100 F, (lower right) Nital etch. 1000×.

Fig. 6—Positive circulation salt bath equipment used in the isothermal studies. Solution salt (left) and (right) quench salt.

temperature goes up. At 1200 F the microstructure showed signs of spheroidization taking place.

The property data obtained from this study holds only within dimension limits of test bars used or where casting sections have comparable quenching rates.

SALT BATH HEAT TREATMENT

Standard and pearlitic malleable tensile test bars were also used in the isothermal transformation treatment study. The type of equipment used in this phase of the investigation is shown in Fig. 6.

The bars were solution treated at 1600 F in molten salt to a structure of austenite and temper graphite, the same as in the quench and temper technique.

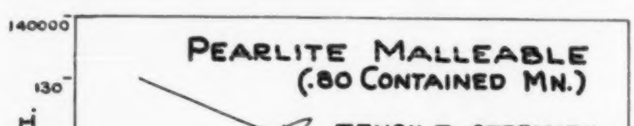

Fig. 7—Typical mechanical properties obtained from pearlitic malleable iron isothermally transformed at various sub-critical temperatures.

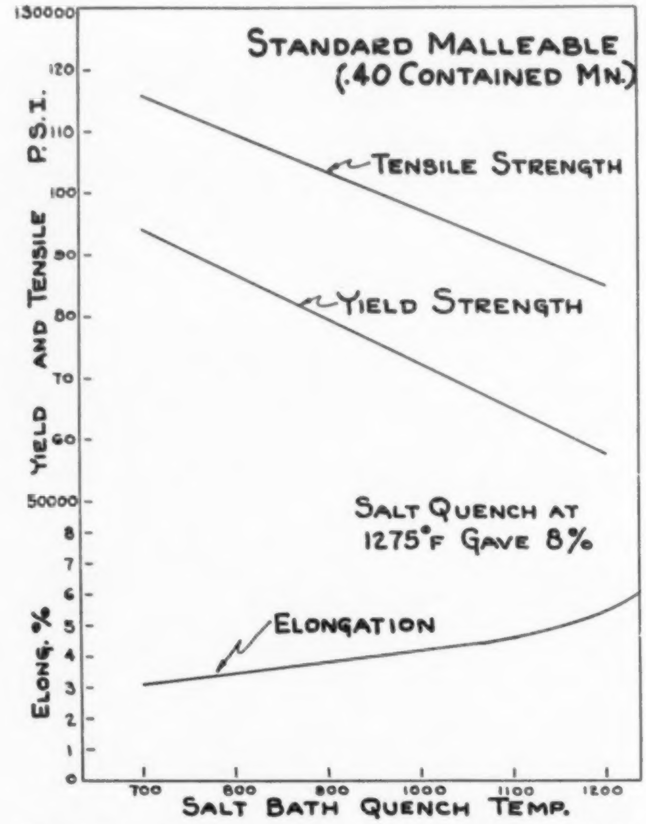

Fig. 8—Typical mechanical properties on regular malleable iron isothermally transformed at various sub-critical temperatures.

After a 20 min soak at temperature, they were quickly transferred and quenched into constant temperature salt baths at various sub-critical temperatures and held sufficiently long for complete transformation to take place. The physical properties obtained from bars isothermally quenched at various temperatures are shown in Figs. 7 and 8.

As can be noted from Fig. 7, a dip in the elongation curve exists between 900-1000 F. The reverse of this characteristic also exists in the hardness curve of the pearlitic base material in Fig. 9. This correlation was not noted in the isothermally treated regular malleable bars as shown in Figs. 8 and 9.

The reason for the absence of the dip in the regular malleable material in the 900-1000 F range was that

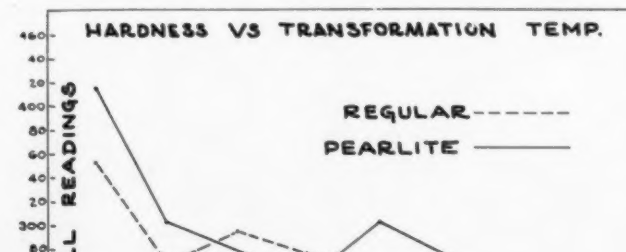

Fig. 9—Hardness valves of regular and pearlitic malleable iron related to isothermal transformation temperature.

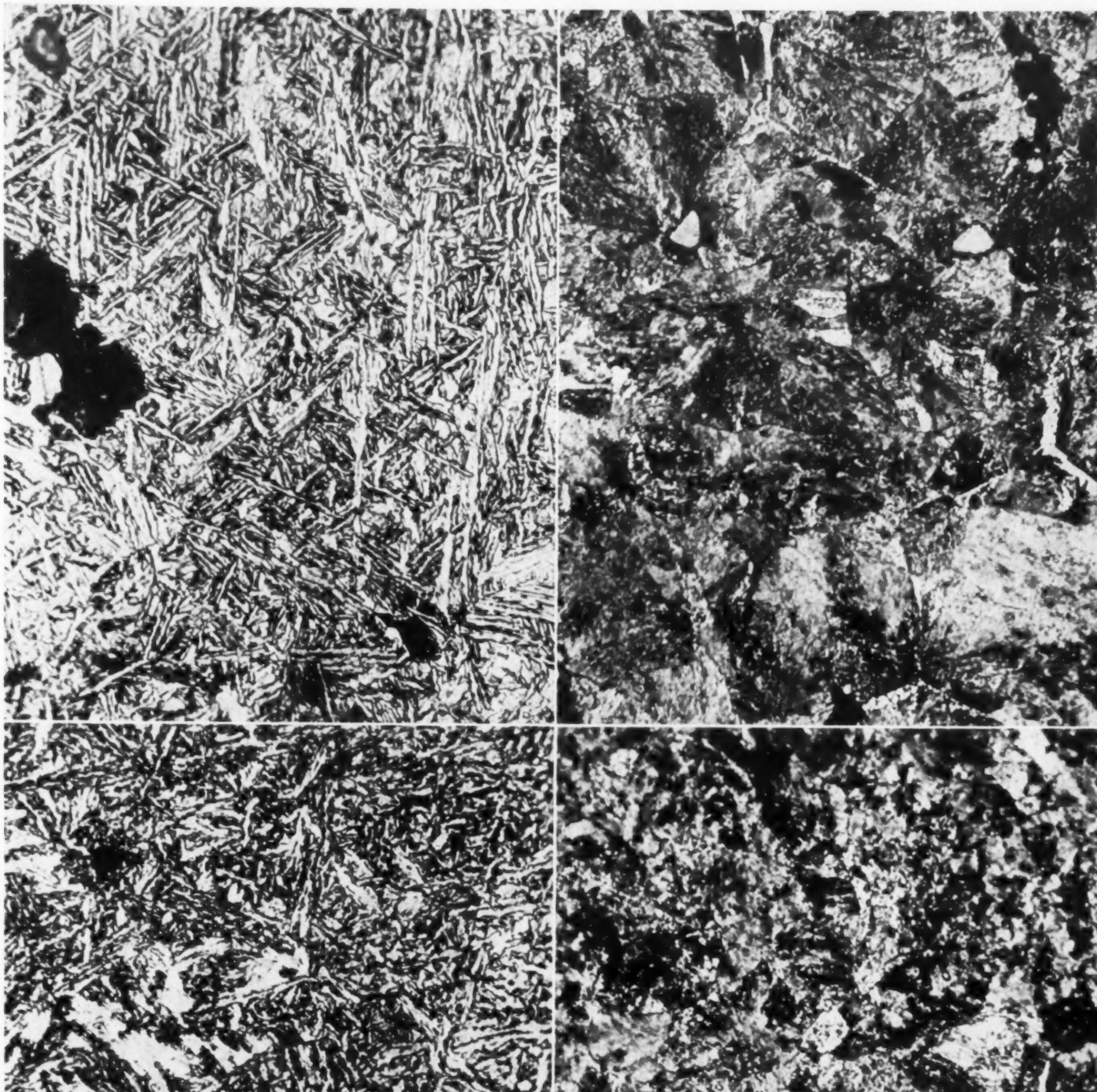

Fig. 10—Photo-micrographs showing the structures obtained by isothermal transformation of regular malleable iron at 700 F, (upper left), at 800 F, (upper right) and pearlitic malleable iron at 900 F, (lower left), at 1000 F (lower right) Nital etch. 1000×.

the critical cooling rate was not exceeded and a mixed pearlitic-acicular structure existed. A slight dip does exist in the 700-800 F range due to the faster rate of quench of the 700 F salt. The quench into 700 F salt was drastic enough to just nick the knee of the "S" curve, and the transformation product was essentially acicular with only a small trace of nodular pearlite present.

The success of the isothermal quench process depends on a knowledge of the "S" curve (for malleable irons it is similar to a S.A.E. 1060 steel). In order to obtain the structure and hardness desired, the section must be cooled at such a rate, from its austenitic range, that no transformation takes place until the desired temperature is reached. The presence of 40 extra points of manganese in the pearlitic bars shifted the "S" curve sufficiently to the right to allow more throat opening time. Photo-micrographs bear this out as shown in Fig. 10.

The transformation product developed, at temperatures from 1200 F down to 1000 F, in the pearlitic were nodular pearlitic, while from 900 F-600 F the transformation product was acicular in nature. With the regular malleable an acicular transformation made its first appearance at the 700 F quench level.

SUMMARY

In summarizing, the following comparisons can be made:—

1. In the oil quench and temper technique, high manganese pearlitic materials have higher tensile and yield values than the regular malleables for a given tempering temperature.
2. For the same hardness values regular and pearlitic materials develop the same elongation and relatively the same tensile and yield strengths.
3. The higher the tempering temperature the softer the product in a straight line function.
4. With salt bath treating, the acicular transformation products have higher tensile, yield and elongation properties than the pearlitic transformation products for comparable hardness levels.
5. Comparing equal hardness values, the acicular transformation products have higher ductilities than the oil-quenched and tempered materials.

Further work in the field of isothermal heat treatment along the line of impact strength should prove worthy. The impact properties of steel are greatly enhanced in isothermal treating over oil-quench and temper to the same hardness.

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1958

CHARLES EDGAR HOYT MEMORIAL LECTURE

SILICON: PRESENT AND FUTURE

By

Walter E. Remmers*

INTRODUCTION

If silicon in its various forms were not available, there would be no meeting of foundrymen here this morning, in fact, there would be no building such as this for us to occupy. There is even a probability that we would be a different people living in an entirely different environment. That silicon plays a fundamental role in our entire existence becomes obvious when we begin to think of its many applications.

Throughout our entire life silicon, in some form, is seldom, if ever, more than an arm's length away. It may be the sand in the concrete floor beneath us, or an alloy in our aluminum chair. It may be in the steel of our automobile, or in the lens of our reading glasses. It is one of the oldest materials used by man. Earthenware jars for food or water were of clay. The weapons and tools of prehistoric man were of flint, and he ignited his fires by striking two pieces of flint together. To this day, silicon in one form or another, continues as one of man's most useful elements.

SILICON ABUNDANCE

It is one of the most common materials in the earth's crust. Next to oxygen, it is the second most abundant element. In nature it is found in the oxide form as sand, or combined as a silicate in some minerals. It is one of the most versatile of the elements, not only in application but in price as well. In the form of sand or gravel it is one of the cheapest of industrial raw materials, whereas, in its highly purified form the cost is several hundred dollars per lb, a range of about 1-1,000,000.

Because the use of silicon in its various forms is so widespread, it would not be possible to cover all of them in any single discussion. Therefore, let us consider silicon as it is used in present-day applications that involve metallurgical and kindred processes of interest to most of us, and then look toward developments in the future. If I speak of subjects closely related to the interests of my company, it is because the author's company has been actively associated with the development of silicon products and processes from the earliest days.

Although impure forms of silicon had been produced, ferrosilicon was of no interest commercially until Henry Bessemer found that the addition of silicon to blown metal from a converter produced sound steel. This was just a century ago, so in effect we are now celebrating the centennial of the use of silicon in steelmaking. Interest in silicon increased at a rapid rate after Hadfield published the results of his comprehensive investigation of the effects of silicon in steel. His important discovery of the effects of several per cent of silicon on the magnetic properties is responsible for the high silicon electrical steels of today.

EARLY MANUFACTURE

Once the remarkable metallurgical advantages of using silicon became known, a demand was created for a material that was not readily available at that time. It was de Chalmot in 1893 who began the electric furnace manufacture of ferrosilicon at Spray, N. C. This was in the plant of a predecessor of Electro-Metallurgical Co. A graphic sketch of a submerged arc furnace as used in the production of ferrosilicon is shown in Fig. 1. The earlier furnaces were not covered as is this one.

Commercial alloys of silicon and iron can be obtained today in compositions that range from relatively pure iron to extremely pure silicon.

Although elemental silicon is classed chemically as a non-metal, it does possess metallic characteristics

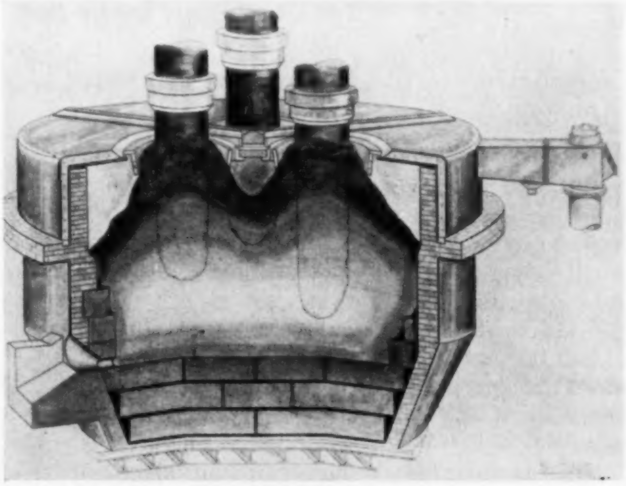

Fig. 1—Cross-section of modern covered submerged arc furnace.

*Vice-President, Union Carbide Corp., New York.

so it is no surprise that the purer grades of silicon for alloying purposes are known as silicon metal.

Because it weighs less than one-third as much as iron, the ferrosilicons are lighter than iron. Ferrosilicon gradually becomes nonmagnetic as the silicon content increases through the range of 15 per cent to about 21 per cent and remains nonmagnetic throughout the higher silicon contents.

You are familiar with the many grades of ferrosilicon, along with a substantial number of other alloys of silicon with chromium manganese, and many other metals.

SILICON IN STEEL

Silicon is one of the most extensively used ferroalloy elements, being second only to manganese among the alloy materials used by the steel industry. In practically all grades of steel, except rimmed steel, some silicon is required. Even in rimmed steel, small additions are used for control purposes. The silicon content of finished steel ranges in amounts of less than 0.02 per cent almost continuously to 5 per cent, with a few foundry specifications as high as 9 per cent-14 per cent.

The use of silicon as an alloy in steel is very well known by all of you for increasing yield, tensile and fatigue strengths in engineering steels, for the purpose of decreasing hysteresis loss in electrical steel, or for improved oxidation resistance in stainless steel. An estimated saving of $800,000 was effected by constructing a bridge of alloy steel, instead of carbon steel as used in adjacent structure. A silicon alloy steel was used for the highly stressed members of this new bridge.

The 50 per cent grade is the principal ferrosilicon used by the steel industry, mainly as a ladle addition. However, substantial quantities of other grades such as 75 per cent are used as a mold addition for capping semi-killed steel, as a mold coating for special steels, and for addition to high silicon steels. The 15 per cent grade sometimes known as silvery pig iron, is used for blocking open hearth heats. However, many steel makers prefer silico-manganese for this purpose for its greater effectiveness and improved cleanliness of the steel.

In the early development of alternating current electrical power it was found that the energy loss in motors and generators was excessive. It was only through Hadfield's discovery of the beneficial effects of 1 per cent-5 per cent silicon on the magnetic properties of steel that use of alternating current grew to maturity.

Silicon-Electrical Cores

Without silicon-electrical cores in the transformers high tension distribution of power plants would not have been possible. We would probably have many small power plants widely distributed, instead of large scale centralized generation.

I am sure you agree with me that without alternating current as a practical system of electric power, electrical energy would cost more and our industrial economy would be vastly different from what it is now.

The manufacture of high silicon electrical steel created a demand for higher silicon and lower impurity grades of ferrosilicon, and so we find 65 per cent, 75 per cent, and 85 per cent in special as well as in regular grades being developed. The use of these materials is particularly interesting in that an addition of solid 65 per cent ferrosilicon to molten steel results in no heat being gained or lost, whereas the higher silicon alloys are quite exothermic and generate heat when added.

In addition to the foregoing, pressures for other metallurgical improvements developed aircraft quality alloy steels, weldable high strength steel, and high temperature alloys.

As a result, there are now a number of binary and complex silicon compositions for special purposes, such as calcium-silicon for developing ball-type inclusions in bearing steels and for reducing hot-shortness in the high nickel alloys; calcium-manganese-silicon for deoxidizing, increasing ductility, reducing hot shortness, or desulfurizing through heavy additions. Some of the other alloys for special purposes are zirconium-silicon for non-aging, titanium-silicon for high-temperature purposes, and iron-aluminum-silicon for deoxidation.

Low-Carbon Alloys

But silicon is of great importance to the steelmaker in an entirely different way as well. Dr. Becket, who was responsible for developing the manufacture of low carbon ferrochrome in the arc furnace, found that silicon could be used as an economical chemical reagent in producing low carbon ferroalloys, such as ferrochrome, ferromanganese and ferromolybdenum. In his procedures, silicon replaces carbon as a reducing agent.

When present in increased amounts, it displaces carbon in the product. This made possible the production of ferrochrome-silicon, an alloy very low in carbon content. When the silicon in such an intermediate low-carbon alloy is oxidized by a metallic oxide such as chrome ore, low-carbon, low-silicon ferrochrome is produced. Except for the more recent solid-decarburized ferrochrome, and a very small amount of aluminothermic alloys, practically all of the low-carbon ferroalloys of chromium and manganese are made by variations of this process.

It is notable that silicon displaces sulfur too, so that low-carbon ferrochromium and ferrochrome-silicon are very low in the content of this element. This is particularly fortunate because the stainless steels in which these are used are quite sensitive to the effect of sulfur on hot-shortness.

The substitution of silicon for carbon is likewise utilized for the preparation of special alloys such as zirconium-silicon, titanium-silicon, calcium-silicon, and calcium-manganese-silicon. These would otherwise be made by an aluminum reduction or by some other means.

In Stainless Steel Making

Another development of this process is the use of silicon in the form of ferrosilicon or ferrochrome-silicon to reduce chromium from the slag in making stainless steel. This is quite essential for increasing the recovery of chromium in the oxygen-blown process. With economic pressures to use the lowest cost source of chromium in the furnace charge and do

more refining in the furnace, the use of silicon as a reducing agent in stainless-steel making will increase.

The process of producing ferromolybdenum is quite different but it too uses silicon as a reducing agent. In this case, the ferrosilicon contains a substantial amount of aluminum which contributes to the efficiency of the reduction and to the exothermicity of the reaction.

When discussing steel, another seldom thought-of contribution of silicon should be mentioned. In the sink and float process of concentrating iron ore, magnesite and other minerals, crushed 15 per cent ferrosilicon is used as the densifying medium. Crushed to 60 or 80 mesh, this grade is suspended in water to provide the desired increase in density. It is magnetic for easy recovery and is oxidation-resistant so that intermittent operations do not cause rusting and caking.

With the need for magnesium metal at the beginning of World War II, 75 per cent ferrosilicon became important as a new reducing agent for the solid state reduction of magnesium from dolomitic limestone.

SILICON IN IRON

The use of silicon to control the structure of iron and the properties of castings is well known in the foundry industry. Since the early evaluation of iron by fracture tests, foundrymen have been seeking improved quality at low cost. The increased use of scrap tended to lower the total carbon content. Some foundrymen corrected this carbon deficiency through the use of lower silicon, higher carbon grades of pig iron in the charge and providing the needed silicon in more concentrated form, either in the furnace or in the ladle.

Silicon additions to the cupola or air-furnace charge are made in the form of crushed ferrosilicon briquetted with a cement binder, as 15 per cent pig, or as specially sized lump 50 per cent ferrosilicon.

Comparative costs of achieving the desired results are usually the determining factor in selecting the form of addition. The protective cement binder of briquets and the opportunity to use more scrap provides some advantage.

Crushed ferrosilicon in the range of 75 per cent-90 per cent was found to be a useful ladle or spout addition for its rapid solution and for its effectiveness as an innoculent. Subsequently, a number of ladle and spout alloys were developed to produce uniformity in high-strength irons without seriously affecting the machinability. These alloys which improve tensile strength and transverse properties, generally contain silicon with manganese, zirconium, calcium, or other metals in properly balanced proportions to effect a strong graphitizing innoculation.

In Ductile Iron Making

Well known in the industry was the further demand for a ductile iron as-cast. To fill this demand and for better control of physical properties, the use of magnesium with silicon was found to be a desirable contribution for innoculation. Nickel-silicon-magnesium and magnesium-bearing ferrosilicons were produced as effective ways of adding it. Several ductile

Fig. 2—Ductile iron paper mill gears, still good after 2 years where cast iron wore out in 6 months.

iron paper-mill gears are shown in Fig. 2. They are still in use after two years, whereas, normal life of the same gears when cast in ordinary cast iron was about six months.

Some grades of magnesium-ferrosilicon contain small percentages of the rare earth metals up to 1/2 per cent for neutralizing unwanted elements that inhibit the formation of spheroidal graphite.

In the malleable foundries, a need for reduced time and better control of annealing brought about the production of a boron-containing 50 per cent ferrosilicon. The boron tends to nullify deleterious effects of some impurities and thereby accelerates annealing.

A sulfuric acid plant uses a substantial number of high silicon castings for their corrosion-resistant properties. In this plant, the 9 per cent silicon castings were specified.

SILICON IN DIE CASTING

The largest consumption of silicon metal is in the production of aluminum alloys for the foundry and for the die-casting industry. Some of these may contain as much as 12 per cent silicon. Improved fluidity and decreased hot shortness are the beneficial effects of the silicon.

For maintaining a low-calcium content in aluminum alloys, a low-calcium grade of silicon metal is available.

Silicon carbide, well known to the foundryman as a grinding wheel abrasive of large tonnage and long-time production, is used as raw material by the chemical industry in producing silicon tetrachloride for manufacturing compounds such as ethyl silicate and white carbon black which is silica in an extremely fine particle size.

SILICON IN INVESTMENT CASTING

Ethyl silicate, so essential to the investment casting industry, provides an adhesive, heat-resistant form of silica for bonding the investment or mold body. Figure 3 shows a tree of investment cast stellite valve seat inserts before being removed from the gate. Ethyl silicate as a source of silica has contributed immeasurably to the enormous growth of the investment process in which castings are made from patterns that are too intricate to be drawn in sand. An exceedingly fine silica coating on the pattern

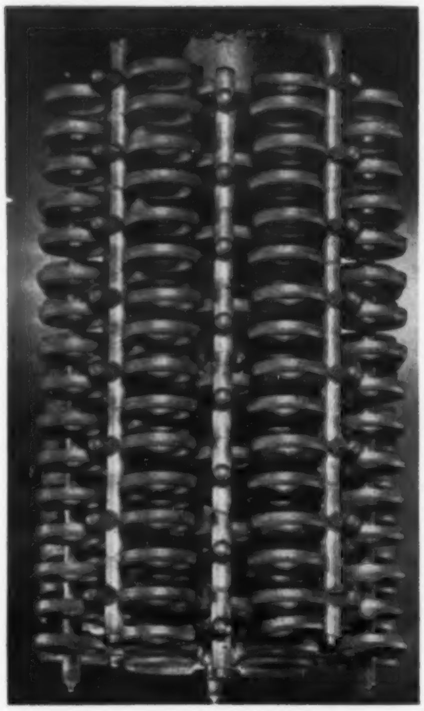

Fig. 3—Investment castings for internal combustion engine valve seat inserts before separation from gates and risers.

before investment shown being applied in Fig. 4, produces a casting of rather accurate dimensions with a smooth surface. A minimum of grinding is usually sufficient for finishing.

Investment casting using ethyl silicate has been used to produce numerous small parts from dentures to blading for jet engines. Development has now proceeded to the point that castings as complicated as the entire wheel of a turbo-supercharger can be produced readily as a single casting.

The use of some types of electrical apparatus at high temperatures has been limited by the ability of rubber and other insulating materials to withstand the elevated temperature. Likewise, in aircraft and other types of internal combustion engines, a need developed for lubrication and rubber parts that would endure at higher temperatures. Here again we find ubiquitous silicon playing an interesting role as the important element in a group of synthesized organic chemicals known as silicones. These substances are polymers wherein silicon atoms replace certain carbon atoms in chain compounds.

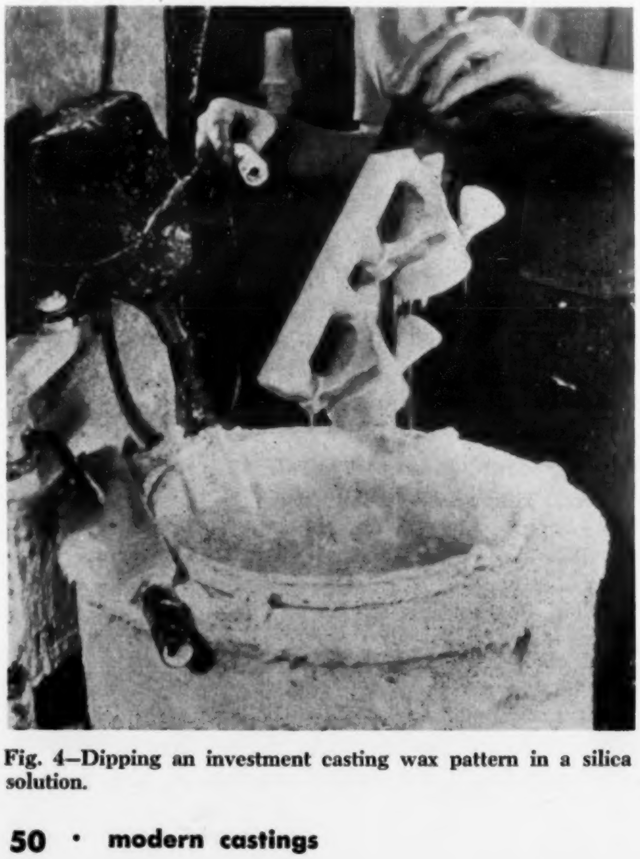

Fig. 4—Dipping an investment casting wax pattern in a silica solution.

SILICONES

To produce silicones, silicon metal is reacted with organic materials in large continuous reactors. The resulting mixtures of organo-silanes are separated in fractionating columns, and then polymerized into oils, resins, and rubbers under accurately controlled conditions. The products are a unique group of over 150 different and versatile man-made chemicals which are unknown in nature. For example, the squeeze roll for combining plastic and paper for counter tops is made of silicone rubber.

These silicones are notable for their heat stability, dielectric properties, good resistance to chemical attack, and for their unusual surface activity.

Thus silicone oils, because of heat stability and other properties, find use as high-temperature lubricants, hydraulic fluids, and electrical oils. Silicone rubber is used in electrical apparatus and appliances such as motors, electric irons, ovens, and special wiring where high-temperature service is important. A motor stator being dipped into a silicone solution for high temperature insulation and moisture-proofing is shown in Fig. 5. Its utility at both high and low temperatures is the reason for military vehicles, ships, aircraft, and submarines consuming large quantities.

The usual surface properties of silicones have led to their use in cosmetics and water repellents, as anti-foaming agents, and as the important constituent of the modern wipe-on, wipe-off automobile polishes.

In shell molding, an emulsion of a silicone oil serves as a pattern dressing for improved mold release. Sludge buildup is practically eliminated.

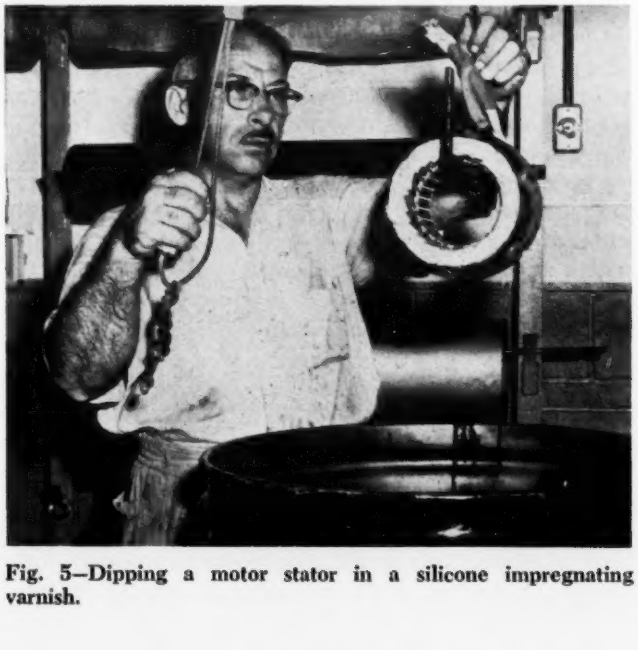

Fig. 5—Dipping a motor stator in a silicone impregnating varnish.

Fig. 6—Pouring brass castings by the shell molding process. A silicone release agent is used in making the shell mold.

Shell molding, well known to most foundrymen, consists of two mold halves produced by covering a hot pattern plate with a mixture of sand and phenolic resin. The resin quickly sets with the sand into a smooth, hard shell, ready for assembly into a mold to receive molten metal. Figure 6 is a brass foundry pouring operation where shell molding is used. Good finish, accurate dimension, and almost infinite storage life of the shells are the advantages well known in the industry.

One variety of silicone possesses an aversion for water. When this colorless material, dissolved in a volatile hydrocarbon, is freely applied to a masonry surface the solvent evaporates without sealing the surface. The brick work and black marble exterior of a district office building has been waterproofed with no change in appearance. The almost paradox is that a porous masonry surface turns back the water as a result of the repellent properties of the absorbed silicone.

If you have been watching the television performances recently, you may be aware of the use of silicones in lotions to prevent chapped hands, and in baby powders to prevent diaper rash. We might say that silicones reduce irritation in nursery as well as in foundry.

SILICON VS. ELECTRICITY

Silicon and germanium are electrically active elements, yet they are not classed as conductors or as nonconductors of electricity, instead they are known as semi-conductors.

The electrical characteristic of semi-conductors has resulted in one of the outstanding scientific and industrial developments of today. Several scientists working at a telephone company laboratory developed a small device utilizing crystals of germanium and silicon. These devices, known as transistors, are electric valves that control the flow of energy in electrical circuits in much the same manner as a vacuum tube. Similarly small diodes and larger rectifiers operate as valves that pass current in only one direction and block it in the other.

Although, as a semi-conductor, germanium is easier to use in transistors, silicon of controlled high purity has become the important material for transistor and diode crystals. In addition to being abundant, it is able to perform at elevated temperatures of 200-300 C, and can operate at higher power levels than germanium.

Transistors, with their small size, minute power requirements, and greater dependability, are replacing vacuum tubes. You know of this use in miniature radios, but there are extensive applications in broadcast equipment, aircraft apparatus, machine tools, computers, and for many other purposes. Their small size and reliability makes possible the control of guided missiles and messages from man-made planets. In our daily living these devices provide the possibilities of many more conveniences, such as automatic controls and individual communication. A portable transistor phonograph can operate off of two flashlight batteries.

HIGH PURITY SILICON

Silicon, with impurities of not more than 10^2-10^{-2} ppm is required for these new devices, depending upon the application. Until recently, purity of this order was unobtainable by any known metallurgical process, in addition to being beyond measurement by established procedures.

To produce these high purity crystals of silicon, entirely new procedures in metallurgy were required. New concepts of solid solubility, crystal growth, nucleation, diffusion, and other phenomena were incorporated into processes such as zone refining and zone leveling developed by a telephone company laboratory. To produce the highest level of purity, the unwanted impurities are swept through a rod of hot silicon. This is done by pushing them ahead of a solid-liquid interface with the noxious elements advancing in the progressing liquid phase. When they reach the end of the rod and solidify, they are discarded mechanically.

In a somewhat similar manner, the desired elements to be introduced into a high purity rod in controlled amounts is brushed through the rod leaving an infinitesimal, but desired quantity behind. These new technologies, when applied to other metals, may afford an opportunity for study of entirely new areas of high purity metallurgy.

When the same electrical phenomenon of permitting flow of current in only one direction, such as in the diode, is applied to larger units of greater current-carrying capacity, they are known as rectifiers. The use of silicon as a semi-conductor in rectifiers for converting alternating current to direct current is new and expanding rapidly. Silicon diodes and rectifiers are much smaller and more reliable than some of their predecessors. They are replacing vacuum tubes, mercury-arc rectifiers, and motor-generator sets.

The ability of a silicon rectifier to operate at higher temperatures and consistently at higher power throughout, permits a tremendous reduction in size that is especially significant in applications where weight and space must be conserved. Silicon rectifiers are being produced in units of increased current carrying capacity with one manufacturer now building a 400-amp direct-current arc welder using this principle.

Rectifiers use a lower grade of high purity silicon than transistors. This permits refining by recrystallization from a molten bath of silicon through the introduction of a seed crystal at a carefully controlled temperature in an inert atmosphere. The rod thus formed on withdrawing the slowly solidifying silicon may be cut to size for use when no further refining is necessary.

Although sales of semi-conductors are doubling and even tripling annually, the effect has been stimulating for a tremendous growth in the entire electronic industry. Total sales of the various semi-conductor devices are expected to reach a level of at least $500,000,000 by 1965.

SILICON IN SOLAR CELLS

Silicon possesses one additional characteristic that may prove to be of great importance, that is the ability to convert light into electrical energy. When sunlight impinges on the surface of silicon electrical energy is generated. A unit performing this function is known as a solar cell. Its life appears to be indefinite. Assemblies have been designed that will generate as much as 25-watts and capable of supplying 5-watts over a 24 hr period.

Although this is still relatively small in terms of power, solar cells nevertheless provide opportunities for energizing unmanned transmitters, weather stations, and similar devices. A sun-powered hearing aid is a very recent development. The entire power unit consisting of the silicon solar cell and a tiny storage battery is mounted in one temple bar of horn rim eyeglasses, with the hearing unit in the bar on the opposite side. It is reported that the light on a slightly overcast day will provide sufficient power to operate the transistor hearing aid without drawing on the battery for additional energy. The battery operated transistor hearing aid is completely contained in one side. The solar cell operated hearing aid is similar in appearance.

SILICON COMPOUNDS

Research scientists have not been devoting all of their attention to pure silicon, some have been studying silicon compounds too. The silicones are one group of complex organic chemicals that have evolved from this research interest. There are a number of other developments in the field of binary inorganic compounds of silicon similar in chemical makeup to well-known silicon carbide. A few of the newer ones beginning to attract attention are silicon nitride, molybdenum disilicide, and silicon monoxide. Some of these are so new that chemical and physical data are still being accumulated.

Silicon nitride, for example, has been known for many years but was largely a laboratory curiosity until 1948 when the author's company's researchers started an investigation of its physical and chemical properties. Produced by nitriding silicon metal in an atmosphere of nitrogen at relatively high temperatures, silicon nitride shapes and powder are emerging in a field of usefulness that could be extensive. Articles can be produced by slip casting, pressing, or by extruding, without the addition of any outside bonding material. They possess strength, chemical stability, a high degree of hardness, and good resistance to thermal shock.

A useful characteristic of silicon nitride is that most of the molten nonferrous metals hardly wet it. In its initial applications it has been used for thermocouple protection tubes and small melting crucibles where freedom from contamination is important. It has been tried successfully for coating ladle linings and in mold washes for sand castings. Crucibles and boats are used for such zone refining or leveling, because silicon nitride is not wet by molten germanium or molten silicon.

Silicon nitride, with its resistance to high-temperature oxidation and high-velocity erosion, is being tested for coating graphite nozzles of rockets and as a solid insert in the throats of rocket nozzles. Although other insert materials have surpassed it in static tests, its low density may be an important factor in a missile where weight is so critical.

Molybdenum Disilicide

Another compound of silicon and molybdenum, known as molybdenum disilicide, is a new product that may be useful for similar high temperature erosion applications. It can be fabricated in ways similar to those for silicon nitride. Its greater resistance to high-temperature oxidation and erosion is offset to some extent by its lower resistance to thermal shock and its weight which is more than twice that of silicon nitride.

Silicon Monoxide

Silicon monoxide is another of the newer inorganic compounds of silicon for which applications are still being found. Its use until recently has been limited to the protective coating of optical and photographic lenses and reflectors of powerful searchlights. Through a process of high-temperature vaporization, a coating is deposited that is so thin it transmits light, and yet it is hard enough to withstand scratching, abrasion of use and exposure.

A fascinating and new application of silicon monoxide is in the outer coatings of the U. S. Navy Vanguard planets now whirling in outer space. This is not done for abrasion-resistant purposes, but is based on the ability of silicon monoxide to absorb a band of radiation of given wave length. The planet is coated with two very thin layers of silicon monoxide alternately on flash coatings of chromium and aluminum. In this way it is possible to predetermine the amount of radiation to be absorbed by the planet and thereby limit the inside temperature to a range satisfactory for operation of contained apparatus.

Silicon, an abundant element from the commonest of raw material, has a future as challenging as man conquering space.

CAST AGE-HARDENABLE AUSTENITIC STEELS

By

E. A. Lange, N. C. Howells, and A. Bukowski*

ABSTRACT

Cr-Ni-P, Cr-Mn, and Cr-Ni-Mn-V types of age-hardenable austenitic steels which have high-strength characteristics in wrought forms were investigated for use as high strength, nonmagnetic steels for castings. A Cr-Ni-P austenitic steel with 0.3 per cent C and 0.25 per cent P developed yield strengths at the 100,000 psi level. The Cr-Mn type of austenitic steels containing phosphorus or vanadium were age hardenable, but castings of these alloys were brittle when they were heat treated to high-strength levels. Modifying the wrought Cr-Ni-Mn-V composition resulted in an alloy with good ductility and yield strengths at the 100,000 psi level.

A fourth type of age-hardenable, austenitic steel, Mn-V, containing a minimum of alloying elements was developed. Four compositions which were cast and heat treated to yield strengths at the 100,000 psi level are reported.

INTRODUCTION

Naval engineers designing hardware for minesweepers are handicapped because they lack suitable high-strength, nonmagnetic casting alloys. Nonferrous alloys and conventional austenitic steels have limitations with regard to yield strength, modulus of elasticity, endurance limit or machinability. In recent years, compositions of wrought steels with austenitic microstructures have been developed that can be age hardened to high hardness levels and yield strengths in the range of 88,000 to 147,000 psi.[1,2,3]

The heat treatments of these alloys consist of a solution anneal at temperatures in excess of 2000 F followed by a water quench and then aging for periods up to 20 hr at temperatures between 1200 and 1400 F. The increase in hardness during the aging treatment results from a precipitation of minute carbides throughout the microstructure. Large primary carbides remain in many alloys after forging and rolling operations, but they are discontinuous and evenly distributed throughout the microstructure and thus do not present a problem for ductility.

The applicability of three types of these wrought alloys for use in castings was investigated. A fourth type of alloy having no direct wrought counterpart was developed that contains a minimum amount of nickel. The tensile properties reported were obtained with the various alloys heat treated to maximum hardness levels with the intention of demonstrating the potential merit of the composition. The establishment of optimum ductility properties of the alloys of potential merit requires additional research.

PROCEDURE

All of the steels were melted in a basic-lined induction furnace having a 100 lb capacity. Armco iron was used as the base metal and appropriate quantities of master alloys were added to obtain the desired compositions (Table 1). A flow of dry helium was introduced during the meltdown and the superheating period through a loosely fitted cover to minimize hydrogen pickup and oxidation of chromium and manganese. Keel blocks and cylindrical test bars were cast at 2850 F directly from the furnace.

The test bar casting (Fig. 1) was designed to simplify the preparation of specimens for hardness and tensile tests as many of the alloys were difficult to machine even in the solution annealed condition. A cylinder 4-in. tall with a 2-1/2-in. diameter, gated from the runner of the casting in Fig. 1, was included for each type of alloy to determine its solidification characteristics. A Pt-Pt 13 per cent Rh thermocouple was positioned in the center of the cylinder, and the cooling curve was obtained with an electronic temperature recorder.

The high chromium-nickel steels were poured in a conventional western bentonite bonded silica sand, but the molds for alloys with a high manganese content were prepared from the sand mixture presented in Table 2.

The cylindrical test bars were solution annealed for 1 hr at 2100 F and water quenched. The specimens for the hardness tests were then cut with an abrasive

TABLE 1 – NOMINAL ANALYSES OF MASTER ALLOYS FOR PPT.-HARDENING AUSTENITIC STEEL HEATS*

	High Carbon Ferro-Manganese %	Lump Manganese %	Ferro-Vanadium %	Ferro-Molybdenum %	Ferro-Phosphorus %	Ferro-Chromium %	Ferro-Silicon %
Iron	13.0	1.8	68.0	41.0	76.0	30.0	50.0
Carbon	6.7	0.13				0.06	
Manganese	80.0	98.0					
Vanadium			31.0				
Molybdenum				59.0			
Phosphorus					24.0		
Chromium						70.5	
Silicon							50.0

***Base metal—armco iron: 0.03% C, 0.01% Si, 0.005% P.**

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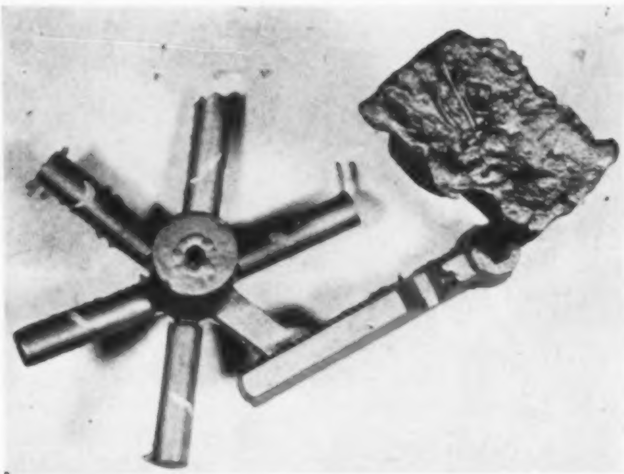


Fig. 1—Test bar casting. Total weight = 30 lb; Bar dimensions 1 in. dia. × 4 in.

TABLE 2 – SAND MIXTURE FOR HIGH MANGANESE STEEL

Material	Per cent by Weight
Zircon Sand	89.6
Silica Sand	4.7
W. Bentonite	0.5
S. Bentonite	1.5
Corn Flour	0.5
Core Oil	1.0
Water	2.2

wheel. The disc-shaped specimens were aged for periods up to 20 hr at 1200, 1300, and 1400 F and oil quenched. The hardness of the specimens was determined with a Brinell machine after the Rockwell C hardness test proved to be inconsistent.

Tensile specimens were machined from keel blocks or cylindrical bars in the solution annealed condition. The machined bars were then aged to maximum hardness and tested.

Each alloy was given a "Go – no go" magnetic permeability test at various stages of heat treatment with a 1.2 permeability indicator. The area which had been deformed by the Brinell ball was tested for magnetic permeability to indicate the stability of each alloy. The Brinell impressions were at mid-radius positions, so the permeability test results were not affected by the surface which had been oxidized during the solution anneal heat treatment. Oxidation during the aging heat treatment discolored the flat surfaces of the specimens, but the extent of oxidation was insufficient to offset the magnetic permeability test.

DISCUSSION OF RESULTS

The steels in this investigation may be divided into four general classifications based upon chromium, manganese, and nickel contents. A listing of the four classifications is given in Table 3 showing the composition range of the primary alloying elements. The steels in the first three classifications were patterned after wrought compositions, which reportedly can be precipitation hardened to 0.2 per cent yield strengths in excess of 120,000 psi with elongations between 13 per cent and 20 per cent, but the fourth type of alloy had no wrought counterpart.

Cr-Ni-P Austenitic Steels

The Cr-Ni-P group of alloys is essentially an age hardenable 18-8 stainless steel. The carbide precipitation causing a substantial increase in hardness during an aging treatment at 1300 F is promoted by phosphorus. Initial experiments with these alloys were concerned with determining the proper balance between carbon and phosphorus for maximum age hardening without retention of an excessive amount of massive carbides after the solution anneal heat treatment. The base composition used was:

%Cr	%Ni	%Mn	%Si	%Mo
17.5	10.5	0.5	0.5	0.5

with carbon contents: 0.12 per cent, 0.29 per cent, 0.39 per cent; and phosphorus contents: 0.12 per cent, 0.20 per cent, 0.30 percent. For these experiments the specimens for hardness testing were cut from 100 lb keel blocks poured at 2925 F. The specimens were solution annealed at 2100 F for 1/2-hr and quenched in water.

Microstructures of the various alloys in the solution anneal condition are shown in Fig. 2. Note the large grain size and residual coring. Grain boundary carbides and grain boundary cracks can also be observed. Samples of each composition were age hardened at 1200, 1250, 1300, and 1350 F with holding times extending to 24 hr. It was found that the alloys were not sensitive to overaging, and the maximum level of hardness was attained within 24 hr at all temperatures except 1200 F.

The relationship between C, P, and hardness is shown in Fig. 3. Increasing the phosphorus content promoted an increase in hardness at all carbon levels, but 0.20 per cent phosphorus appeared to be the threshold value for substantial age hardening. A composition with a minimum amount of phosphorus is desirable, however, because the phosphorus forms a complex eutectic with carbon, chromium, and iron. The complex eutectic may promote "bleeding" during solidification if the melt contains appreciable amounts of nitrogen or hydrogen, or may liquify during the solution anneal heat treatment.

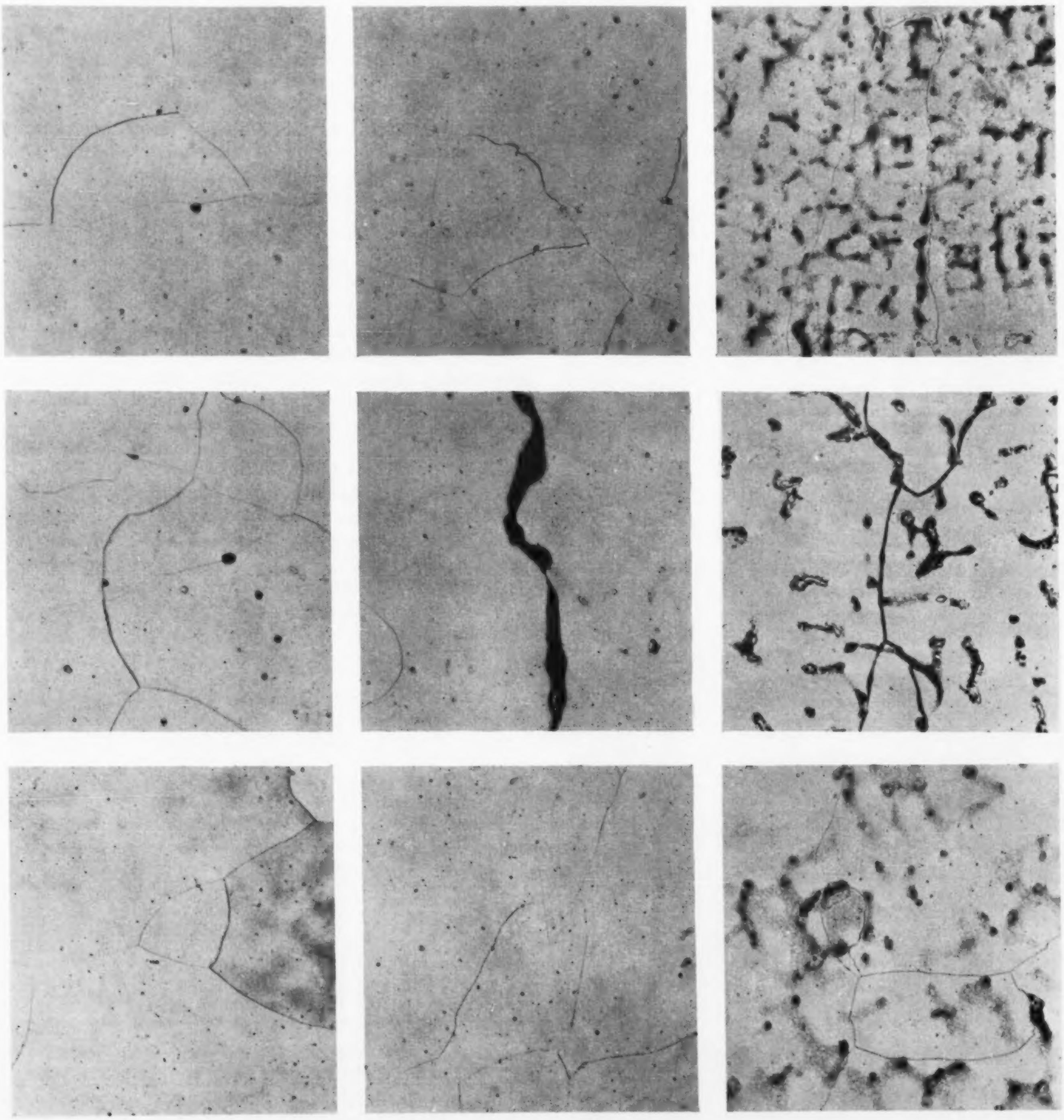
The tensile specimens from these initial steels were aged to hardness levels of 230 to 415 BHN. Unfortunately, the tensile strength and elongation values were of little significance because either cracks were formed during heat treatment or grain boundary carbides (Fig. 2) were present, and the specimens fractured in a brittle manner at low loads.

TABLE 3 – CHEMICAL COMPOSITION OF FOUR TYPES OF AGE HARDENING AUSTENITIC STEELS

Alloy Type	Composition—%						
	Cr	Ni	Mn	C	P	V	Mo
1. Cr-Ni-P	16.5–19.0	8.0–11.0	0 – 3.5	0.1 –0.4	0.1–0.3	–	–
2. Cr-Mn	12.0–16.0	–	12.0–16.0	0.1 –1.0	0 –0.3	0 –1.2	–
3. Cr-Mn-Ni	4.5– 6.0	5.5– 9.0	9.0–11.0	0.5	–	0.3 –1.1	–
4. Mn-V	0 – 4.5	2.0– 4.0	14.0–18.0	0.25–1.2	–	0.25–1.2	0.4–3.5

The base composition of the alloy was then modified to increase the stability of the austenite by adding 3.5 per cent manganese and eliminating the molybdenum addition. Carbon and phosphorus levels were maintained at 0.34 per cent and 0.25 per cent respectively, and smaller keel blocks, cylindrical test bars and plates 1 x 6 x 9-in. were cast. Tensile test bars were machined from the castings and heat treated to maximum levels of hardness. The highest properties were obtained in the keel blocks and end sections of the plates. Chromium oxide laps in the cylindrical bars and center sections of the plates formed planes of weakness in the test bars. The tensile properties that were considered to indicate the potential merit of the Cr-Ni-P alloy are given in Table 4.

The values presented in Table 4 demonstrate that a Cr-Ni-P alloy can be used for castings with magnetic permeability less than 1.2 and yield strengths in excess of 100,000 psi. It is believed that the tensile properties of this type of alloy can be greatly improved over those given in Table 4 by further modi-



	%C	%P
Top –	0.12	0.10
Center –	0.29	0.10
Bottom –	0.39	0.10

	%C	%P
Top –	0.12	0.20
Center –	0.29	0.16
Bottom –	0.39	0.21

	%C	%P
Top –	0.12	0.32
Center –	0.29	0.28
Bottom –	0.39	0.31

Fig. 2—Microstructures of Cr-Ni-P austenitic steels. Solution annealed condition. Marble's reagent etch. 50×.

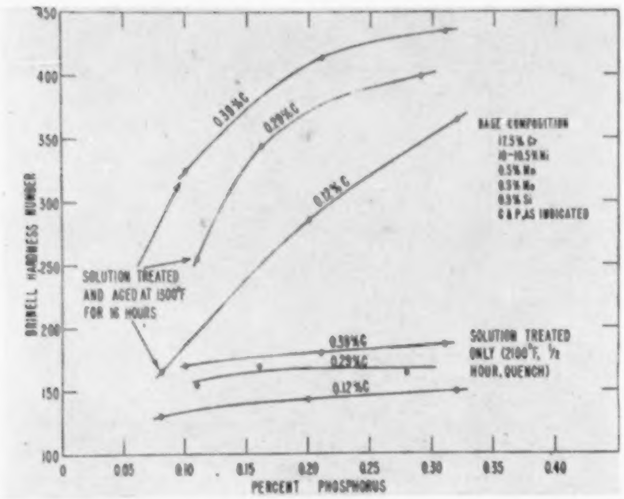
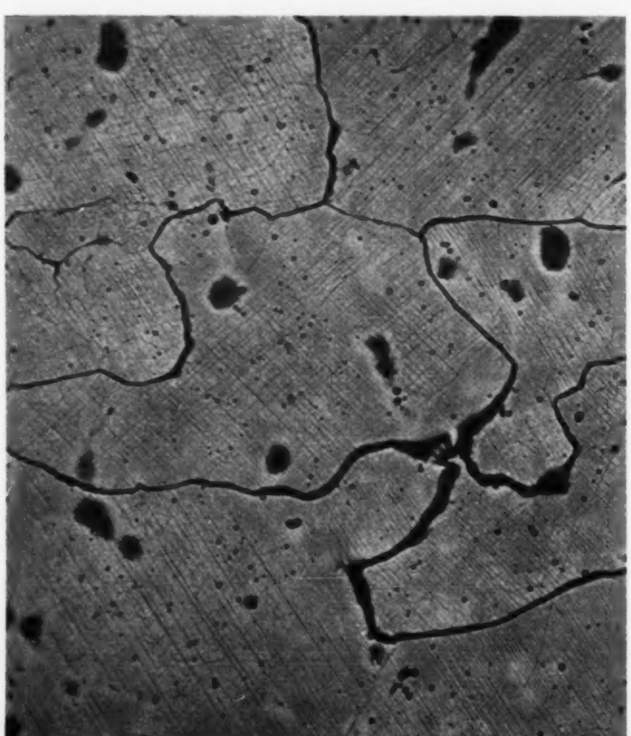


Fig. 3–Effect of carbon and phosphorous on the hardness of Cr-Ni-P austenitic steel.

fication in composition, improved foundry practice, and optimum heat treatments. The high chromium content permitted very little oxidation to occur during the solution anneal heat treatment at 2100 F in a normal furnace atmosphere.

Cr-Mn Austenitic Steels

Manganese substitution for nickel in high chromium steels is desirable because of possible limitations in the availability of nickel. A high carbon-vanadium-12 per cent chromium steel with no nickel has shown high strength properties in wrought form following an aging treatment of 8 hr at 1300 F.[4] The following properties were reported: 195,000 psi T.S., 160,000 psi Y.S., 15 per cent El., 22 per cent R.A. Test castings with compositions comparable to that of the wrought alloy were made and given an age hardening heat treatment. The chemical composition, hardness, and tensile properties are given in Table 5.



%Cr	%Mn	%Ni	%V	%C
12.3	9.6	2.0	0.6	0.31

Fig. 4–Illustrating the carbide network in age hardened Cr-Mn austenitic steel. BHN = 241. Chromic acid etch. 50×.

Alloy 2 with 0.64 per cent C and 1.5 per cent V developed a high hardness level during the aging treatment, but it was brittle. With reduced carbon and vanadium contents the alloy either contained sufficient grain boundary carbides to produce a brittle structure (alloy 3) or the alloy had insufficient age hardening to meet the proposed requirements (alloy 4). Figure 4 illustrates the continuous grain boundary carbide network, etched dark, that is typical for the Cr-Mn type alloys containing sufficient vanadium to promote an age hardening reaction. Because of the embrittling effect of the carbide network these alloys are basically not suitable for castings.

The possibility of inducing age hardening characteristics by the use of a phosphorus addition was also investigated with the Cr-Mn alloy. Two alloys were cast having the following compositions:

Alloy No.	%Cr	%Mn	%Mo	%C	%P	BHN	Comment
5	13.1	13.1	3.5	.25	0.25	375	Magnetic
6	13.9	13.9	3.3	.55	0.24	415	Excessive cracking

The low carbon alloy (No. 5) had a hardness of 240 BHN in the solution annealed condition and increased in hardness to 375 BHN after aging for 16 hr at 1300 F. This substantial increase in hardness demonstrated that phosphorus will promote age hardening in a high chromium-Mn alloy as it does in a Cr-Ni alloy. Unfortunately, the magnetic permeability of this alloy was greater than 1.2, which is excessive. Alloy 6 with a higher carbon content was nonmagnetic, but fine radial cracks developed during machining which resulted in very poor mechanical properties, 67,500 psi T.S. with 0 per cent elongation. Further development with the Cr-Mn alloys to eliminate the cracking tendency was not pursued.

Cr-Mn-Ni-V Austenitic Steels

The composition of this class of alloys was also based on wrought compositions which reportedly have yield strengths greater than 150,000 psi, and are

TABLE 4 – TENSILE PROPERTIES OF FULLY AGED HARDENED Cr-Ni-P AUSTENITIC STEEL, ALLOY NO. 1, 17-18.5% Cr, 9-10.5% Ni, 3-4% Mn, 0.25% C, 0.25% P

Casting	Age Treatment	TS (psi)	YS (psi)	% El.	% R. A.
Keel block	8 hr – 1350 F	130,500	124,500	4	5.0
Keel block	16 hr – 1350 F	130,000	120,000	4	3.9
1-in. plate	16 hr – 1300 F	142,000	113,000	2	1.5
1-in. plate	16 hr – 1300 F	153,000	136,000	1	1.7

NOTE: Magnetic permeability of all test bars was less than 1.2 in the age hardened condition.

TABLE 5 – COMPOSITION, HARDNESS, AND TENSILE PROPERTIES OF Cr-Mn AUSTENITIC STEELS

Alloy No.	Composition – %						Max	Δ	TS	%
	Cr	Mn	Ni	Si	V	C	BHN	BHN*	(psi)**	El.
2	12.2	15.2	—	0.76	1.5	0.64	375	160	140,000	1
3	12.3	9.6	2.1	1.2		0.83 0.36	272	60	110,000	3
4	12.8	9.6	2.0	0.30	0.6	0.31	241	40	—	—

* Δ BHN = Increase in hardness during the aging treatment.
** Heat treatment: 2100 F for 1 hr, W.Q.; 1300 F for 16 hr, O.Q.

nonmagnetic.[4] These alloys have chromium contents of 5-7 per cent which is much lower than the chromium contents of the Cr-Ni-P and Cr-Mn alloys. The Cr-Mn-Ni-V alloys also contain a balanced amount of Ni and Mn for good austenitic stability. Age hardening is promoted with vanadium and a moderate amount of molybdenum.

Four compositions were investigated for this class of alloys to determine the proper balance between vanadium and carbon. The compositions, hardness values, and tensile properties of the alloys in a fully aged condition, are given in Table 6.

The composition of alloy 7 in Table 6 is essentially the same as the composition of a wrought alloy that attained 175,000 yield strength with 13 per cent elongation after a similar heat treatment. The high hardness level of the wrought alloy (44.5 Rc) was attained in the castings, but the ductility of the cast metal was essentially nil. The rolling or forging operations which mechanically redistribute the carbide remnants appear to be mandatory for obtaining a high-strength, ductile alloy with this composition.

The compositions of alloys 8, 9, and 10 in Table 6 were modified to improve ductility. The carbon content was reduced in alloy 8 from 0.65 per cent-0.28 per cent which decreased the maximum hardness in the aged condition, but the reduction in hardness was not reflected by a comparable increase in ductility (0.3 per cent). The vanadium content was reduced in alloy 9 from 1 per cent-0.42 per cent. This modification in composition decreased the hardness of the alloy in the solution annealed condition, but substantial age hardening characteristics were maintained and the ductility was greatly improved. The tensile properties of alloy 9 in the aged condition were 93,000 psi Y.S., 105,000 psi T.S., and 11.0 per cent elongation.

Further reduction in the vanadium and carbon contents (No. 10) caused the alloy to lose its age hardening characteristics. It thus became apparent that the vanadium content was the critical carbide forming element and that chromium might even be detrimental to an age hardening cast alloy because of the tendency for chromium carbides to form at grain boundaries. Since this class of alloys contained a rather high percentage of nickel (7 per cent) further research was concerned with a new class of alloys which contained a minimum amount of nickel and relied primarily on manganese and accompanying nitrogen for austenitic stability.

Mn-V Austenitic Steels

The Mn-V age hardenable austenitic steels are a new class of compositions which were developed as a result of the work with the Cr-Mn-Ni-V alloys. Unlike Hadfield steels the MnV steels do not depend upon carbon as a principle austenite former, and carbon is present only in sufficient quantities for obtaining the desired level of hardness during the aging heat treatment. Manganese is the principle element for promoting austenitic stability in the Mn-V type of steel, and for this investigation the manganese content ranged from 14 per cent-18 per cent. However, a small amount, 2 per cent-4 per cent, of nickel was found necessary to stabilize the age hardened austenite in plastically deformed areas and maintain a magnetic permeability less than 1.2. Nitrogen was also present in these alloys and no doubt acted as an austenite former, but nitrogen was not given individual attention.

TABLE 6 – COMPOSITION, HARDNESS, AND TENSILE PROPERTIES OF Cr-Mn-Ni-V AUSTENITIC STEELS

Alloy No.	Composition – %						BHN Hardness		Tensile Properties		
	Cr	Mn	Ni	V	Mo	C	Max.	Δ *	TS psi **	0.2% YS psi	% El.
7	6.1	8.9	8.5	0.9	3.1	0.65	445	235	148,000	––	0.5
8	5.8	9.6	5.5	1.08	3.3	0.28	345	175	100,000	99,000	0.5
9	5.7	7.5	7.2	0.42	3.4	0.52	388	200	105,000	93,000	11.0
10	6.2	9.5	6.0	0.31	3.2	0.24	155	40	––	––	––

* Δ BHN = Increase in hardness during the aging treatment.

** Heat treatment: 2100 F for 1 hr, W.Q.; 1200 F for 20 hr, O.Q.

TABLE 7 – COMPOSITION AND TENSILE PROPERTIES Mn-V AUSTENITIC STEELS

Alloy No.	Composition – %							Tensile Properties*		
	C	Mn	Ni	Si	V	Mo	CR	TS psi	0.2% YS psi	% El.
11	0.44	14.3	3.5	0.54	0.33	0.42	–	108,000	95,000	4.0
12	0.41	16.3	3.2	0.44	0.20	3.50	–	123,000	113,000	3.0
13	0.43	16.6	3.3	0.59	0.70	3.50	–	125,000	110,000	1.0
14	0.46	16.6	2.8	0.65	0.40	3.3	2.2	138,000	137,000	1.0
15	0.35	14.0	3.1	0.38	0.34	3.1	4.0	875,000	70,000	3.0

*Heat treatment: Solution treatment 1 hr 2100F W.Q.; Aging treatment 16 hr 1300F O.Q.

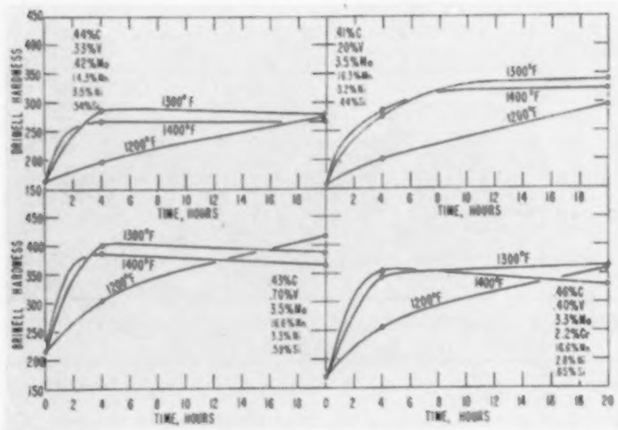
Vanadium was found to be the indispensable carbide-forming element for producing age hardening characteristics. The age hardening characteristics of an alloy containing a minimum of 0.2 per cent vanadium could be increased by adding molybdenum, but molybdenum by itself did not produce a significant response to an age hardening heat treatment.

Chromium, when added alone, did not induce a favorable age hardening reaction, but unlike molybdenum, chromium did not support vanadium in the formation of a general precipitate. The age hardening characteristics of Mn-V alloys were not affected by small amounts of chromium (up to 2 per cent) but larger amounts (4 per cent) had a notable softening effect.

The compositions and tensile properties of four Mn-V austenitic steels with yield strengths in a fully age hardened condition approaching or greater than 100,000 psi, are given in Table 7. Alloy 15 was included with this group of high-strength alloys to illustrate the softening effect of chromium. Alloy 15 has a slightly lower carbon content than the other alloys, but the decrease of 10 points in carbon content does not fully account for the change in their age-hardening characteristics.

The age-hardening characteristics of the alloys in Table 7 are shown in Figs. 5 and 6. Samples of each alloy were solution annealed for 1 hr at 2100 F, water quenched, and then aged for periods up to 20 hr at 1200, 1300, and 1400 F. It can be noted that the effect of temperature on hardness during the aging treatment is similar for all of the alloys. The hardness increased at a slow, uniform rate at 1200 F and a maximum level of hardness was not attained even after 20 hr. With aging temperatures of 1300 and 1400 F the maximum hardness levels of alloys 11, 13, and 14, containing 0.33 per cent, 0.70 per cent, and 0.40 per cent V respectively, were attained in 4 hr.

Over-aging as reflected by a decrease in hardness was not apparent with longer aging periods (20 hr at 1300 F) but a definite decrease in hardness was



Top — Alloy 11 Top — Alloy 12
Bottom — Alloy 13 Bottom — Alloy 14
Fig. 5—Age hardening characteristics of Mn-V austenitic steel.

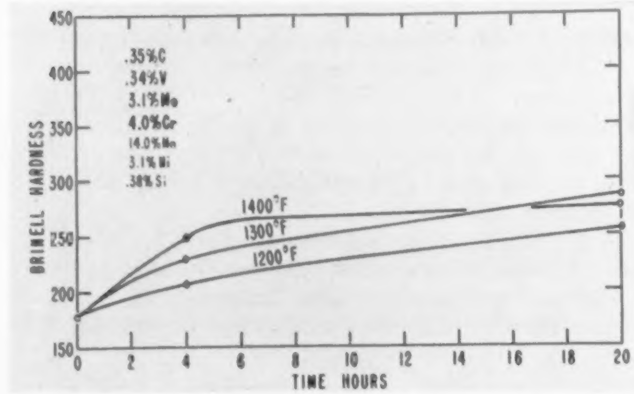


Fig. 6—Age hardening characteristics of Mn-V austenitic steel containing 4 per cent chromium, Alloy 15.

noted after 8 hr at 1400 F. Even though these alloys are not sensitive to over-aging, a temperature of 1300 F appeared best for aging to maximum hardness levels, and temperatures between 1300 and 1200 F appeared best for aging to a controlled hardness level.

The detrimental effect of chromium on the age hardening characteristics of Mn-V austenitic steels can be seen from a comparison of the hardness curves in Figs. 5d and 6. The rate of increase in the hardness of the alloy containing 4 per cent Cr (Fig. 6) is notably less than that for the alloy containing 2.2 per cent Cr (Fig. 5d). Since the Cr-Mn-Ni-V steels contained 6 per cent Cr and developed high hardness levels, the effect of chromium may be related to the austenitic stability of the alloy. Increasing the manganese content beyond 17 per cent or increasing the nickel content beyond 4 per cent may permit a higher level of chromium to be present without impairing the age hardening characteristics of austenitic steels.

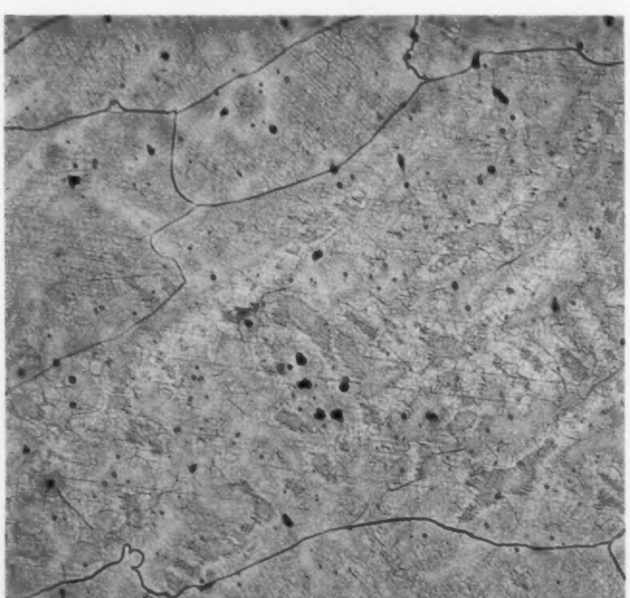


Fig. 7—Typical microstructure of age hardened Mn-V austenitic steel. BHN = 300. Chromic acid etch. 100×.

The tensile properties of the five Mn-V austenitic steels heat treated to maximum levels of hardness are given in Table 7. The individual effects of the carbide forming elements on the age hardening characteristics of Mn-V alloys is not as apparent from a comparison of tensile properties as from a comparison of hardness values. Even though heat treating the alloys to maximum levels of hardness may not have produced the optimum tensile properties, it did serve to demonstrate that the Mn-V type of steels are capable of attaining greater than 100,000 psi yield strengths.

A typical microstructure of the Mn-V austenitic steels in an age hardened condition is shown in Fig. 7. The grains are quite large, but there are only a few scattered carbides at the grain boundaries. Etch patterns indicate that precipitation occurred throughout the slightly cored grains on certain crystallographic planes.

Solidification Characteristics

The austenitic age hardenable steels, except the Cr-Ni-P alloys which have a low-temperature eutectic, solidify as simple solid-solution alloys. The amount of eutectic material in the Cr-Ni-P alloys was too small to be detected by the technique used to obtain cooling curves, so only the bulk solidus temperature was obtained for this alloy. The liquidus and solidus temperatures of the various alloys are shown plotted against the factor C + 1/3 Si in Fig. 8. Even with the wide range of Cr, Ni, Mn, and Mo in the various alloys, the scatter is not very great, and for alloys with carbon contents between 0.3 per cent-0.5 per cent the freezing range was 60-80 F with a solidus temperature close to 2500 F.

The hydrogen content of austenitic steels is receiving increased attention by foundrymen from the standpoint of its void forming capabilities during solidification. An attempt was made to minimize hydrogen pickup during the melting and pouring of the steels for this investigation by maintaining a dry argon atmosphere in the furnace and oven drying the molds. Some shrinkage occurred in test bars, however, which was reduced for several heats by purging the melt itself with the dry gas before pouring. Excessive amounts of dissolved gases are particularly harmful in the Cr-Ni-P austenitic steels, since evolution of gas during solidification and subsequent solution anneal-

ing heat treatment can cause excessive segregation of the complex phosphide eutectic and even exudation of the eutectic material.

Machinability

All of the age hardenable austenitic steels were unmachineable in the as-cast condition. Cutting was essentially restricted to abrasives. In the solution annealed condition and age hardened condition sawing and turning operations were still difficult, and most of the tensile bars were prepared by grinding.

CONCLUSIONS

Four types of alloys were investigated for potential use as high strength, nonmagnetic steels for castings. The following conclusions and recommendations can be made on the basis of the data obtained in this investigation:

Cr-Ni-P Austenitic Steels

1. This type of steel can be cast, solution annealed, and age hardened to attain yield strengths (0.2 per cent) in excess of 100,000 psi.
2. The composition which developed optimum tensile properties was as follows:

%Cr	%Ni	%Mn	%C	%P
18	10	3.5	0.3	0.25

3. Maximum hardness was attained with the following heat treatment:

Solution Anneal:	1 hr at 2100F
Age Hardening:	8 hr at 1350F or 16 hr at 1300F

4. Ductility evaluated as per cent elongation in a tensile test ranged between 1 per cent and 4 per cent.
5. Foundry practices should be aimed at minimizing the hydrogen content of the metal prior to and during casting to avoid excessive segregation and possible exudation of the phosphorus constituent during solidification and the solution anneal heat treatment.

Cr-Mn Austenitic Steels

1. An addition of 0.25 per cent phosphorus with 0.3 per cent C will promote age hardening characteristics in a manganese substituted 18-8 type austenitic steel, but the Cr-Mn-P steels are more prone to cracking than the Cr-Ni-P steels.
2. Age hardening can also be induced in Cr-Mn steels with vanadium.
3. Grain boundary carbides are not eliminated with a solution anneal at 2100 F.
4. No specific composition for castings can be recommended for this type of steel, but base compositions containing more than 13 per cent manganese and 2 per cent nickel are recommended for further research.

Cr-Mn-Ni-V Austenitic Steels

1. The carbon and vanadium contents of the wrought Cr-Mn-Ni-V alloy must be reduced for use in castings to obtain a satisfactory level of ductility.
2. The following composition is recommended for use in castings to maintain proper balance between strength and ductility in an age hardened condition:

%Cr	%Ni	%Mn	%V	%Mo	%C
5.7	8	7	0.4	3.3	0.5

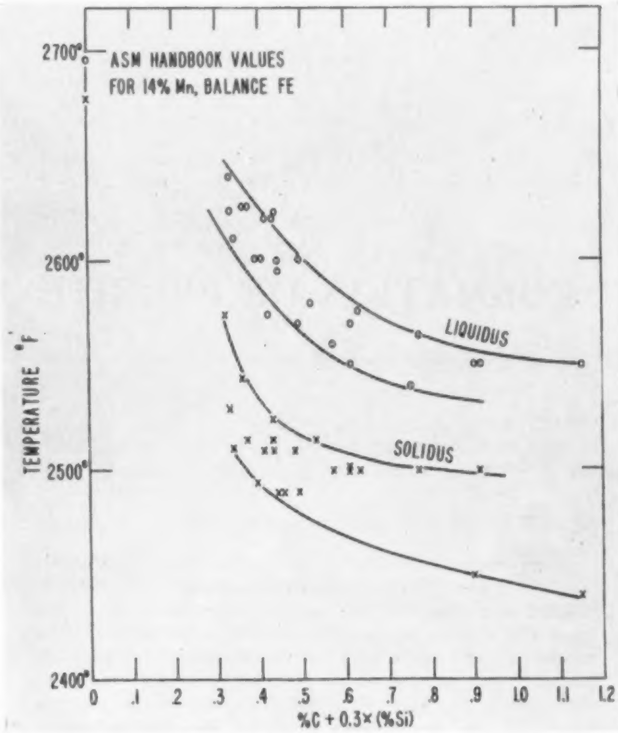


Fig. 8—Liquidus and solidus temperatures vs. composition factor C + 1/3 Si for austenitic steels.

3. Further development work with these alloys is not recommended since the Mn-V austenitic steels have comparable strength levels.

Mn-V Austenitic Steels

1. Age hardening characteristics can be induced in a manganese stabilized austenitic steel by vanadium.
2. A minimum of 0.3 per cent vanadium is necessary to obtain yield strengths of 100,000 psi.
3. Molybdenum supports vanadium in the age hardening reaction, but a minimum of 0.2 per cent vanadium must be present in the alloy.
4. Carbon contents for obtaining high hardness, BHN 300-400, are 0.3 per cent to 0.5 per cent.
5. Chromium contents should be less than 2 per cent.
6. For austenitic stability sufficient to maintain a magnetic permeability below 1.2, the following minimum amounts of manganese and nickel are necessary: 16 per cent Mn and 2.0 per cent Ni.
7. An aging temperature of 1300 F will produce maximum age hardening in a period of 4-8 hr.
8. Aging temperatures between 1200 and 1300 F are recommended for control of hardness.

ACKNOWLEDGMENT

This work is part of a broad investigation of cast austenitic steels conducted at the request of Mr. G. Sorkin, Code 343, Bureau of Ships, Navy Department.

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FORMATION OF FERRITE AND PEARLITE IN CAST IRON

By

G. Ohira* and K. Ikawa**

ABSTRACT

The mode of formation of ferrite and pearlite was studied in the following alloys: iron-carbon, iron-carbon-silicon, and charcoal pig iron. Specimens were cooled from the melt to temperatures between the eutectic and eutectoid, and quenched. At the eutectoid temperature pearlite was nucleated by cementite which had precipitated on cooling after solidification; ferrite crystallized out on precipitated graphite. Pearlite formation was promoted when the iron contained phosphorus or tin. Ferrite formation was promoted by manganese.

INTRODUCTION

The structure of cast iron is generally composed of ferrite, pearlite, and graphite. The subject of graphite formation has been extensively treated in the literature under the solidification mechanism of cast iron. The formation of ferrite and pearlite has received little attention, and should be studied as a matter of solid-phase transformation. There have been a few investigations on the latter subject from the standpoint of the equilibrium diagram[1] of iron-carbon or iron-carbon-silicon, and from the view of isothermal transformation[2], but there is as yet no acceptable description of the mechanism of formation of ferrite and pearlite.

To supply more information on this subject, a microstructural study was made of various alloys which had been cooled from the melt to temperatures between the eutectic and eutectoid, and quenched.

EXPERIMENTAL PROCEDURE

The following alloys were studied: pure iron-carbon, iron-carbon-silicon, iron-carbon-silicon-manganese, and commercial charcoal pig iron (4.22 per cent C, O.48 per cent Si, 0.26 per cent Mn, 0.072 per cent P, and 0.016 per cent S). Excluding the commercial iron, the melting stock for the alloys consisted of electrolytic iron, electrode carbon, 75 per cent ferro-silicon, and electrolytic manganese. Some of the alloys were also prepared with the graphite in the spheroidal form by adding magnesium-copper or magnesium-silicon-iron to the molten base metal.

First, the conditions to obtain a matrix of a) pearlite, b) pearlite with acicular or lump cementite, c) pearlite and ferrite, and d) ferrite were investigated. Specimens of the various irons were melted and continuously cooled at low rates down to room temperature. The effect of manganese on the structure was also determined in this phase of the investigation.

Next, the formation mechanism of ferrite and pearlite was studied. Forty-gram samples were melted in a Tammann tube in a furnace at 1350 C and slowly cooled to various temperatures within the eutectic-eutectoid range, as established by cooling curves. (The cooling rate near the eutectoid temperature was 7-10 degrees/min., or 2-5 degrees/min.) The specimens were quenched in cold water and metallographically examined. The quenched alloy at each step of cooling indicated the structure developed at that time from which the process of transformation could be deduced. The effect of phosphorous and tin was also studied in this phase of this investigation.

EXPERIMENTAL RESULTS

Preliminary Studies

The normal structure of cast iron is composed of flake graphite in a matrix of ferrite and pearlite. This structure was easily obtained in the charcoal pig iron, but not in the pure iron-carbon and iron-carbon-silicon alloys.

Three irons containing 2.5, 3.7, and 4.5 per cent C, respectively, were melted and 3.5 per cent Si added. Each structure consisted of flake graphite in a pearlite matrix with not free ferrite evident. Increasing the silicon to 4.0 per cent did not change the structure of the two lower-carbon irons; however, the structure of the iron containing 4.5 per cent C converted to graphite and ferrite with no pearlite. Coexistence of graphite, ferrite, and pearlite could not be obtained, even by controlling the cooling rate.

Effect of Manganese on the Structure

There have been a few studies made on the effect of manganese on the matrix structure. Coe[3] directed attention to the relation between combined carbon and manganese. Norbury[4] described similar results related to sulfur. Neither investigator considered the effect of manganese itself.

To determine the effect of manganese, pure iron-carbon and iron-carbon-silicon alloys were melted, deoxidized with 0.1 per cent Al, and alloyed with various amounts of manganese. Areal ratios of ferrite

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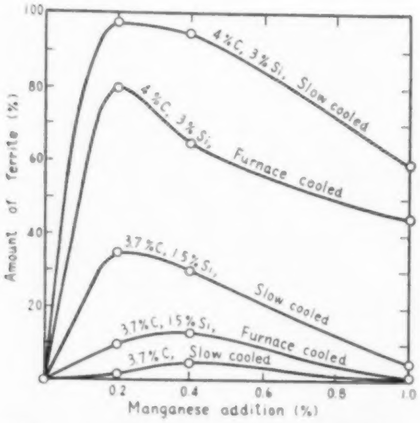

Fig. 1 – Areal ratios of ferrite to pearlite, with various amounts of manganese added, in carbon-silicon-iron alloys.

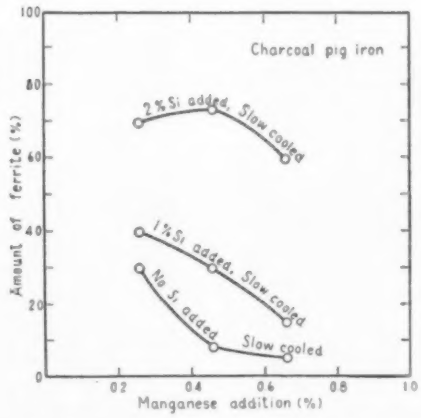

Fig. 2 – Areal ratios of ferrite to pearlite, with various amounts of manganese and silicon added, in charcoal pig iron.

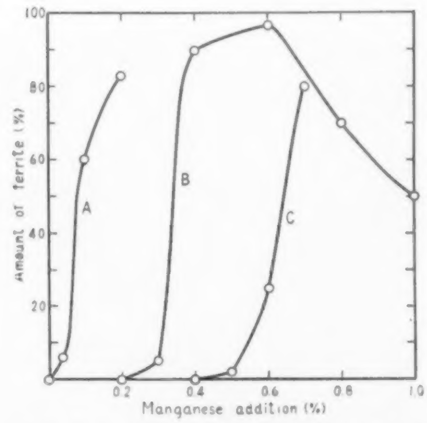

Fig. 3 – Amount of ferrite of various alloys melted and manganese added, in presence of various amounts of sulfur.

to pearlite, as determined metallographically, are shown in Fig. 1. The maximum amount of ferrite was obtained at 0.2 per cent Mn. At all manganese levels, ferrite, pearlite, and graphite coexisted.

Similar results were obtained with charcoal pig iron to which silicon and manganese additions had been made (Fig. 2). Comparison of Figs. 1 and 2 shows that silicon also influenced the ferrite content, and that the amount of ferrite was the same in alloys with the same silicon content.

To investigate the effect of manganese in the presence of various amounts of sulfur, the alloys listed in Table 1 were melted and manganese added. The amount of ferrite in these alloys is shown in Fig. 3. Since some manganese was combined with sulfur as manganese sulfide, the amount of manganese required to obtain ferrite increased with increasing sulfur content.

The reason for the ferrite-forming tendency of manganese is not clear. The small amount of available manganese could hardly stabilize the carbide, but it may possibly promote the diffusion of carbon.

Formation of Pearlitic Matrix with Acicular Cementite

The cooling curve and the structure of a furnace-cooled alloy containing 3.5 per cent C are shown in Figs. 4 and 5, respectively. The matrix is composed of graphite and pearlite with acicular cementite. To investigate the formation of pearlite and acicular cementite, the alloy was quenched from the arrowed points in Fig. 4. The corresponding structures are shown in Figs. 6-9.

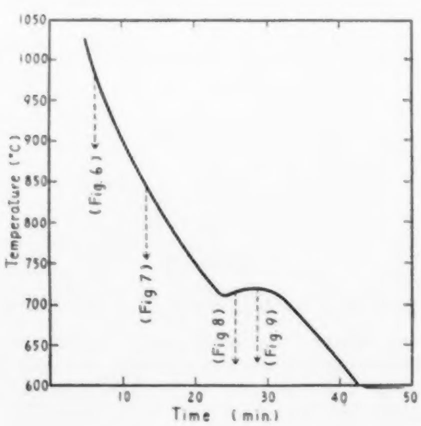

Fig. 4 – Cooling curve of a furnace-cooled alloy containing 3.5 per cent carbon. The alloy was quenched at arrowed points.

TABLE 1–ALLOYS TESTED WITH MANGANESE ADDED

Code Letter	Composition of Irons, %			
	C	Si	Mn	S
A	3.3	1.9	trace	0.01
B	3.4	2.0	trace	0.15
C	3.6	2.1	trace	0.28

Fig. 5 – Structure of a furnace-cooled alloy containing 3.5 per cent C. Picral etch. 130×.

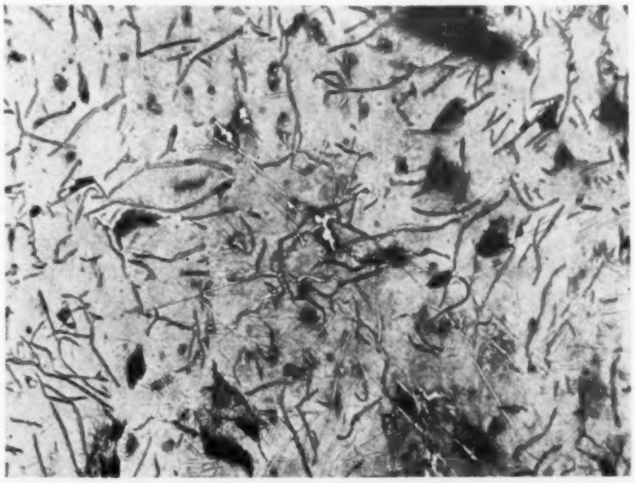

Fig. 6 – Structure showing acicular cementite precipitated on the austenite-graphite boundary in a 3.5 per cent carbon-iron alloy quenched from 990 C. Picral etch. 65×.

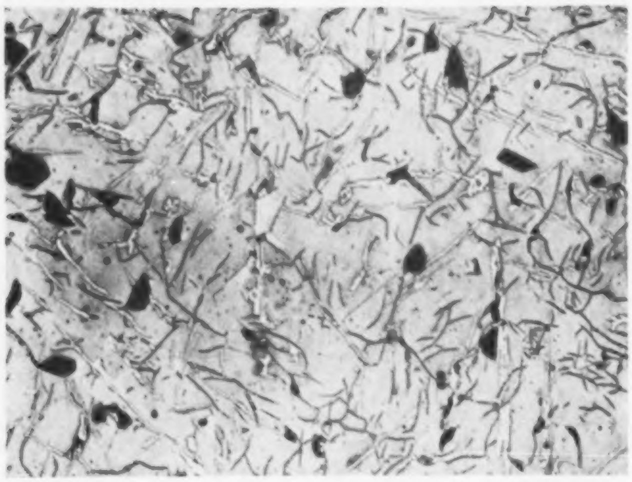

Fig. 7 – Structure showing acicular cementite as it developed following that shown in Fig. 6 for a 3.5 per cent carbon-iron alloy quenched at 850 C. Picral etch. 65X.

Acicular cementite separated from austenite on cooling along the A_{cm} line of the iron-carbon diagram. At first, it precipitated on the austenite-graphite boundary (Fig. 6), then it developed along the graphite flake or crossed the austenite to the next graphite flake (Fig. 7). Lump cementite was deposited at the boundary of the original austenite grains and grew on cooling.

At the eutectoid temperature, these cementite particles became nuclei for pearlite formation (Figs. 8 and 9), and the pearlite spread and covered the entire matrix.

Fig. 8 – Structure showing cementite becoming nuclei for pearlite formation for a 3.5 per cent carbon-iron alloy quenched at the beginning of the eutectoid reaction. Picral etch. 130X.

Fig. 9 – Structure showing cementite and pearlite in matrix of a 3.5 per cent carbon-iron alloy quenched from the middle of the eutectoid reaction. Picral etch. 130X.

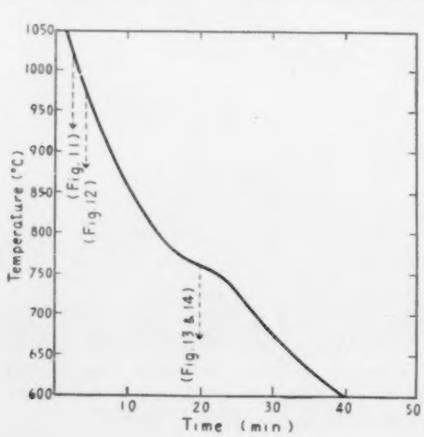

Fig. 10 – Cooling curve of Fe – 3.8 per cent C – Si alloy. The alloy was quenched at arrowed points.

Formation of Pearlite Matrix

The structure of an alloy containing 3.5-3.8 per cent C and 3.0-4.0 per cent Si consisted of graphite and pearlite. The cooling curve of the alloy containing 3.8 per cent C and 3 per cent Si is shown in Fig. 10. The microstructures obtained by quenching from the arrowed points in Fig. 10 are shown in Figs. 11-13.

After eutectic solidification was complete, lump cementite particles precipitated at the boundaries of austenite grains on cooling (Fig. 11), part of which graphitized concurrently (Fig. 12). At the eutectoid temperature, pearlite was nucleated by the cementite and spread (Fig. 13). If the cementite had decomposed to graphite and austenite before eutectoid temperature, austenite would have transformed first to fine pearlite at eutectoid temperature and served as nuclei for pearlite transformation (Fig. 14).

Formation of Ferrite and Pearlite

A matrix of ferrite and pearlite can be obtained

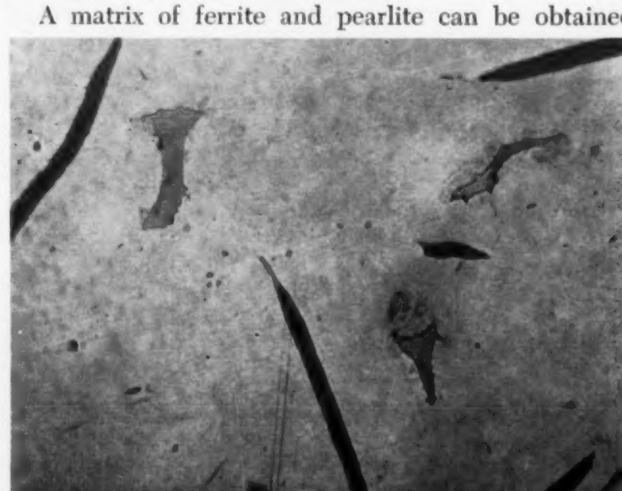

Fig. 11 – After eutectic solidification, lump cementite particles precipitated at the boundaries of austenite grains at cooling for the Fe-3.8 per cent C-3.0 per cent Si alloy quenched from 1020 C. Picral etch. 300X.

in iron-carbon-silicon-manganese and charcoal pig irons.

To study the formation of these constituents, one per cent Si was added to charcoal pig iron to promote ferrite formation. The structures obtained by quenching from temperatures between the eutectic and eutectoid are shown in Figs. 15-19.

After solidification, thin incompletely formed graphite began to precipitate at the edge of flake graphite containing austenite (Fig. 15). The incomplete graphite continued to precipitate during cooling and the austenite contained with the graphite was gradually replaced by graphite (Fig. 16). Graphite precipitation during cooling occurred along the A_{gr} line of the iron-carbon diagram.

At the eutectoid temperature, ferrite was nucleated and developed at the points of incomplete graphite (Fig. 17). When the silicon content was high, ferrite developed and covered the matrix. If the silicon content of the alloy was low, pearlite formation was observed (Fig. 18). A_{gr}-separation around graphite flakes and A_{cm}-separation on austenite boundaries occurred simultaneously during cooling. Occasionally, pearlite nucleated at the boundary of separated ferrite and untransformed austenite (Fig. 19).

Fig. 12 — Part of the cementite and austenite graphitized concurrently for the Fe-3.8 per cent C-3.0 per cent Si alloy quenched from 980 C. Picral etch. 600×.

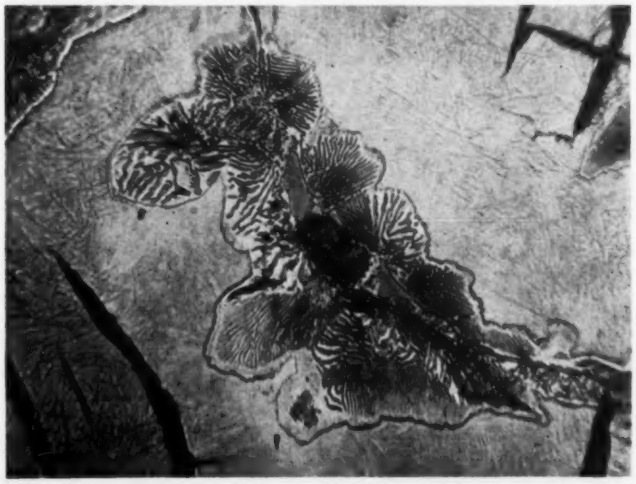

Fig. 13 — Pearlite was nucleated by the cementite and spread when Fe-3.8 per cent C-3.0 per cent Si alloy was quenched at the beginning of the eutectoid reaction. Picral etch. 600×.

The cooling curve of the alloy containing both ferrite and pearlite showed a breaking and an arresting point, while the alloy containing solely ferrite showed only a breaking point (Fig. 20). In Fig. 20, ferrite precipitates from "a" to "b", and pearlite from

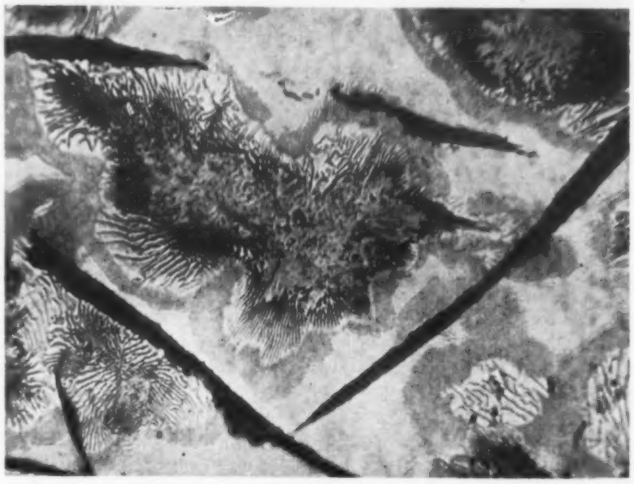

Fig. 14 — Had the cementite decomposed to graphite and austenite before eutectoid temperatures, the austenite would have transformed to fine pearlite at eutectoid and served as nuclei for pearlite transformation for the Fe-3.8 per cent C-3.0 per cent Si alloy quenched at the beginning of the eutectoid reaction. Picral etch. 600×.

Fig. 15 — Structure of charcoal pig iron quenched at the end of the eutectic reaction. Picral etch. 600×.

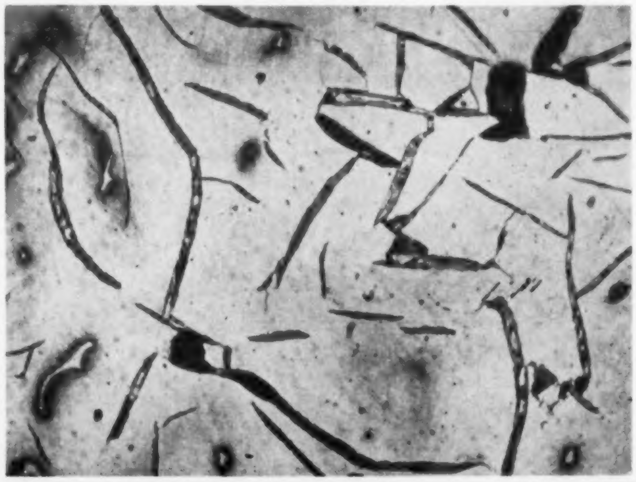

Fig. 16 — Structure of charcoal pig iron quenched from 990 C. Picral etch. 130×.

Fig. 17 – Structure of charcoal pig iron with 1 per cent silicon added quenched at the beginning of the eutectoid reaction. Picral etch. 65×.

"b" to "c". The amount of ferrite was related to the temperature difference between "a" and "b".

Effect of Phosphorus and Tin on the Matrix

When the alloy contained phosphorus, steadite crystallized on the austenite grain boundaries at the end of solidification. At the eutectoid temperature the steadite acted as nuclei for pearlite formation, as did the lump cementite at the austenite boundaries. Figure 21 shows the formation of pearlite around the steadite.

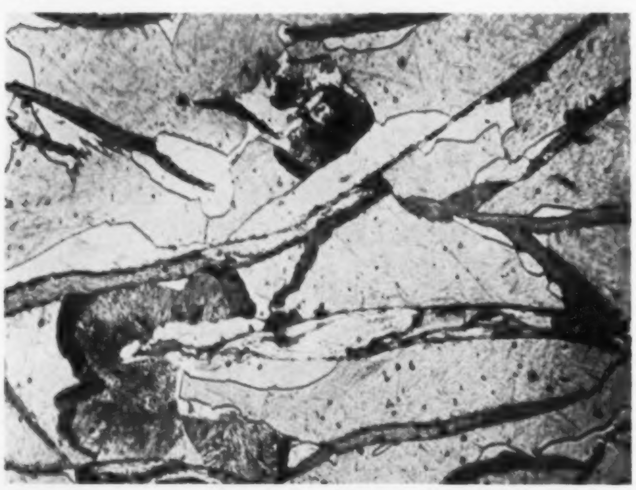

Fig. 19 – Structure of charcoal pig iron with 1 per cent silicon added quenched from the middle of the eutectoid reaction. Picral etch. 240×.

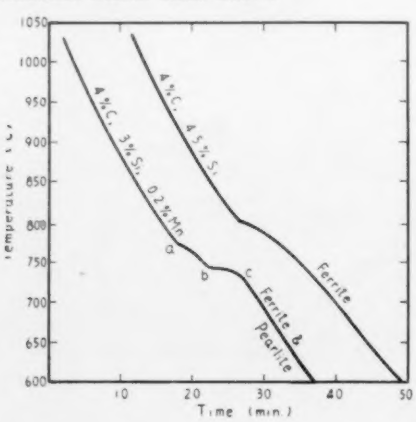

Fig. 20 – Cooling curves of the alloy indicating the formation of both ferrite and pearlite.

Fig. 18 – Structure of charcoal pig iron with 1 per cent silicon added quenched from the middle of the eutectoid reaction. Picral etch. 270×.

In the manufacture of black heart malleable iron, tin is used to accelerate the first-stage graphitization, and retard the second stage. To study its effect in gray iron, tin additions were made to charcoal pig iron at various silicon levels. As shown in Fig. 22, tin was extremely potent in reducing the ferrite content. Quenched specimens of tin-bearing irons showed a new phase at the austenite boundaries from which pearlite nucleated (Fig. 23). It is not known whether this phase is stannid or some other carbide containing tin. It appeared in a specimen containing more than 1.5 per cent Sn and increased with tin content. The specimen was etched white with 5 per cent picral, and brown with a solution of potassium hydroxide and potassium ferricyanide.

Formation of Ferrite and Pearlite in Spheroidal Graphite Iron

The matrix of spheroidal graphite cast iron generally consists of pearlite and graphite surrounded by ferrite. The quenching studies carried out with this material gave similar results to those obtained with normal flake graphite cast iron (Figs. 24-26).

Graphite precipitated as spheroidal graphite along the A_{gr} line of the iron-carbon diagram on cooling

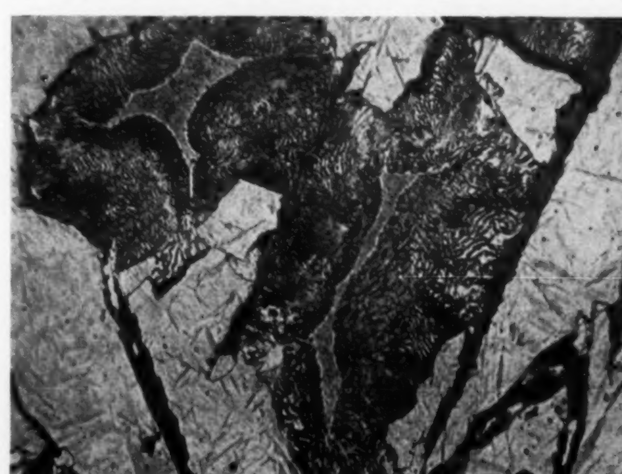

Fig. 21 – Structure of charcoal pig iron with 1 per cent silicon added quenched from the middle of the eutectoid reaction and showing steadite nucleating pearlite. Picral plus KOH solution of $K_3Fe(CN)_6$ etch. 360×.

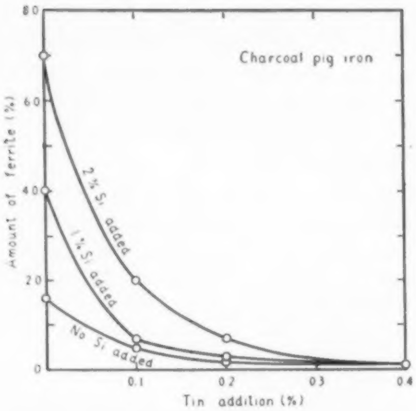

Fig. 22 — Curves showing ferrite vs. tin content.

below the eutectic temperature. At the eutectoid temperature, ferrite was nucleated and developed as shown in Fig. 24. Cementite separated along the A_{cm} line on cooling and acted as nuclei for pearlite formation at the eutectoid temperature (Fig. 25), particularly at the boundaries of original austenite. In some cases, pearlite formation occurred at the boundary of ferrite and austenite (Fig. 26). The mechanism was entirely the same as that with flake graphite cast iron.

Formation of ferrite and pearlite in cast iron with undercooled graphite was also investigated and found to be similar to flake- and spheroidal-graphite irons. Ferrite formation was promoted by undercooled graphite most, spheroidal next, and flake graphite the least.

SUMMARY

The formation of ferrite and pearlite in cast iron was investigated with specimens of iron-carbon, iron-carbon-silicon (flake and spheroidal), iron-carbon-silicon-manganese, and charcoal pig iron. The specimens were melted and quenched after cooling to temperatures between the eutectic and eutectoid temperatures.

The following conclusions were made, based on metallographic examination:

1. It is difficult to get a matrix in which both ferrite and pearlite are found in pure iron-carbon and iron-carbon-silicon alloys, unless a small amount of manganese is added.

Fig. 23 — Structure of Fe—4.0 per cent C—1.5 per cent Sn alloy quenched at the beginning of the eutectoid reaction. Picral plus KOH solution of K_3 Fe $(CN)_6$ etch. 600×.

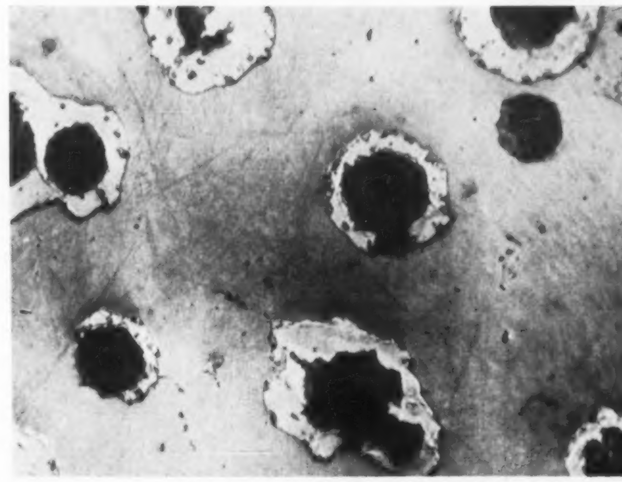

Fig. 24 — Structure of Fe—4.4 per cent C—2.4 per cent Si alloy with Mg added quenched at the beginning of the eutectoid reaction. Picral etch. 240×.

2. Acicular or lump cementite in the iron-carbon alloy is precipitated along the A_{cm} line of the iron-carbon diagram. At the eutectoid temperature, pearlite is nucleated by cementite. Acicular cementite appears on the boundaries of flake graphite

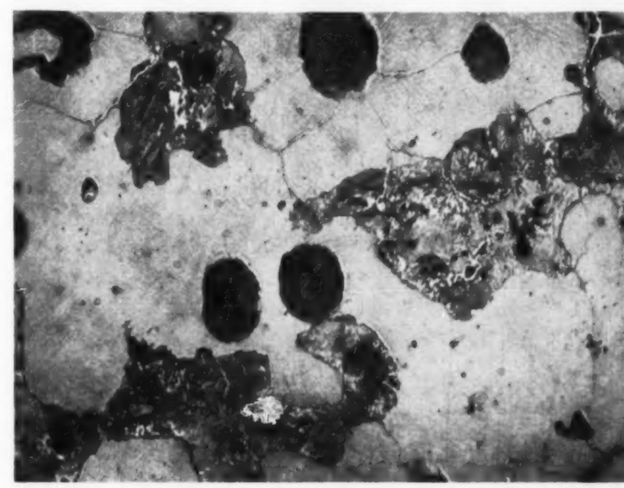

Fig. 25 — Structure of Fe—4.4 per cent C alloy with Mg added quenched at the beginning of the eutectoid reaction. Picral etch. 130×.

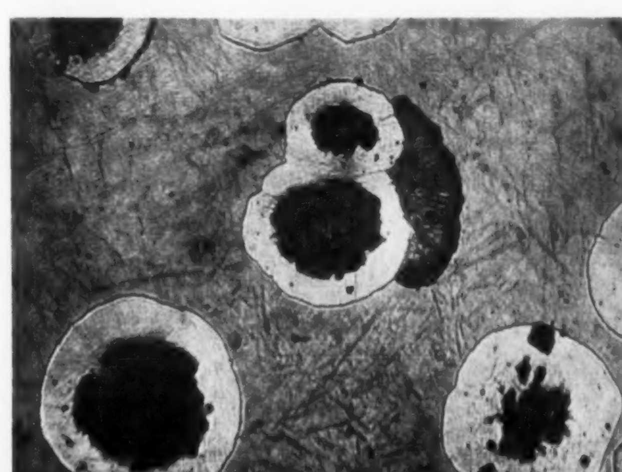

Fig. 26 — Structure of Fe—4.4 per cent C—1.0 per cent Si alloy with Mg added quenched from the middle of the eutectoid reaction. Picral etch. 320×.

and austenite; lumpy cementite appears on those of austenite.

3. In an iron-carbon-silicon alloy containing 3-4 per cent silicon, the lump cementite which precipitates on the austenite boundaries decomposes to graphite and austenite on cooling. At the eutectoid temperature, the austenite transforms first to fine pearlite, and then the pearlite or residual cementite nucleates normal pearlite in the austenite matrix.
4. Frequently, both ferrite and pearlite are seen in iron-carbon-silicon-manganese alloys or in commercial pig iron. Thin flake graphite precipitates on cooling, following the precipitation of the original flake graphite along the A_{gr} line. Ferrite crystallizes out on the graphite at the eutectoid temperature and is followed by pearlite formation. Pearlite appears at the boundary of ferrite and austenite, or at austenite boundaries.
5. The cooling curves of irons which contain both ferrite and pearlite indicate breaking and arresting points. The former corresponds to ferrite formation; the latter to pearlite formation.
6. Pearlite is nucleated by steadite.
7. Iron containing a small amount of tin promotes pearlite and inhibits ferrite. Irons containing more than 1.5 per cent Sn crystallize out some angular particles at the end of the eutectic reaction, which have strong powers of pearlite nucleation at the eutectoid temperature.
8. In spheroidal graphite cast iron, or in undercooled graphite iron, the formation mechanism of ferrite and pearlite is the same as that with flake graphite. Ferrite formation is promoted most in undercooled graphite iron, less in spheroidal, and least in flake graphite iron.

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ALUMINUM MELTING PRACTICE IN THE DIE CASTING AND PERMANENT MOLD FIELDS

By

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INTRODUCTION

During the past 10 years the metal-working industry has shown a tremendous upsurge on a world-wide basis. The growth in the volume of aluminum die castings and permanent molds has been phenomenal, and its pace has outdistanced all other casting techniques in this growth. The growth and wider application of aluminum has introduced many demands on the die-casting and permanent-mold industry as well as the furnace manufacturer. Where previously the users of castings were satisfied with fairly simple shapes and existing standards of surface finishing, today design requirements have introduced the demand for many complicated structures, and the surface finish in most cases is of utmost importance. Higher physical properties and quality control have become absolute necessities.

ALUMINUM ALLOY USES

The tremendous increase in the use of aluminum in the form of cast aluminum alloy products has been accompanied by the need for larger capacity, faster melting, and more economical melting and holding furnace equipment. This metal is replacing many traditional materials, which have been used for years and years, because of its weight advantage and certain of its excellent physical properties. Machinery, hardware, automobiles, and the electrical fields, have offered the greatest growth to aluminum. Fields in which aluminum should continue to grow even more rapidly are the construction field, electrical field, automotive field, as well as the can industry. There is little reason to believe that the use of aluminum will do anything but increase in the years to come. The transportation industry, of course, is another excellent field of growth, as is practically any industry where a weight factor is to the advantage of the over-all cost of operation of the product.

The recent introduction of the vacuum die-casting machine makes the growth of aluminum even more certain. This process, while still in the early stages of development, as far as aluminum is concerned, opens up new horizons to the die-casting technique. The designer has more leeway in integrated, complicated casting designs which formerly required individual castings and subassembly work. The permanent-mold and forging field can now be penetrated due to higher physical properties available. New applications will certainly ensue, due to the possibilities of heat treatment and plating operations at higher temperatures. The possibility of casting low silicon alloys opens up a whole new field for anodized castings which will compete with sheet and extrusions. Competition will become stiffer between stampings and die castings, due to favorable economies of the vacuum die-casting technique applied to die casting.

When die castings and permanent molds were instigated, there were very few applications which required any particularly great quantity of aluminum for one particular casting. Today we have permanent-mold castings in the range of 1,500 lb to 2,000 lb each. Die castings range as high as 75 lb each, with a possible rate of casting of 30 shots to the hr, making an hourly requirement of approximately 2,150 lb. Present experimenting is along the line of casting complete automobile motor blocks, which will still increase present requirements. So, you see, aluminum requirements have grown from a few lb per hr on up to one ton or more per hr. Consequently, new furnace designs have been introduced at every stage to satisfy the melting and holding requirements as they presented themselves.

ALUMINUM PROPERTIES

The melting point of pure aluminum is 1215 F. The heat of fusion is 169 BTU's per lb, and the specific heat is 0.26 (when metal is just above the melting point). Aluminum is seldom used in its pure form and is generally alloyed with other metals or elements, such as copper, silicon, manganese, magnesium, nickel, zinc, etc. Melting points and heats of fusion, of course, would vary slightly with the various commercial alloys utilized.

Every element has certain physical, chemical, and heat conductivity properties which cannot be ignored. For example, aluminum has a tendency to combine with almost every known element in common use. Aluminum readily combines with oxygen to form alu-

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minum oxides. This oxidation problem increases with metal temperature increases. The specific gravity of aluminum and of the aluminum oxides formed are very closely related. Considerable care, therefore, is required to separate the oxide formations from the aluminum bath. The best condition for this separation is to maintain as quiet a bath as possible.

When aluminum is melted in a refractory-lined furnace there is a tendency for an oxide buildup to take place at the metal line or slightly above the metal line. This buildup must be removed daily while the refractory lining is hot, and must never be allowed to remain while cooling the refractory. Once the refractory has been cooled with this buildup present, there is a definite bond formed between the refractories and the aluminum buildup which causes a more or less permanent deterioration of the refractories and reduces the refractory's ability to resist penetration.

Iron Absorption

Aluminum has a tendency to absorb iron, therefore, considerable care is required when melting aluminum in iron-pot furnaces. These iron pots must be washed with a suitable coating regularly so that aluminum does not remain in contact with the iron-pot surface. Other care must be taken also in the operation of the pot furnace itself. It has been the experience of the author's company that variations in temperature increase the action between aluminum and iron considerably. For example, should a bath of aluminum be allowed to freeze in the iron pot over a weekend, and then heat is applied to the iron pot to bring the aluminum into solution, considerably more iron pickup would occur at this period than during the entire day when metal is added and taken away from the furnace. Also, if molten aluminum is held more or less stagnant for long periods at a time in iron pots, there is a tendency for considerable more iron solution.

Gas Absorption

Aluminum has a tendency to absorb certain gases, of which hydrogen is the most troublesome. The ability of the aluminum to absorb hydrogen increases with the temperature of the metal. The absorption rate is comparatively low when the metal is held slightly above the heat of fusion point. When metal temperatures approach 1400 F, however, this absorption ability is almost double. The absorption ability rises rapidly above 1400 F.

Sources of hydrogen can be narrowed down to three possibilities.

1. Moisture may exist on the ingot or scrap metal being charged into the bath.
2. The atmosphere has a certain amount of humidity.
3. Water vapor is produced in the combustion process. This water vapor, if allowed to enter the bath, will break down into hydrogen, and the oxygen will be released to burn or form aluminum oxide. The hydrogen generally is absorbed by the metal and is held in solution.

The first of these sources of hydrogen pickup, mainly the moisture on the metal charge itself, can be easily overcome by preheating the metal up to approximately 900 F. The second source, namely, the humidity of the atmosphere, will vary considerably throughout the year and has always been a problem in casting operations. There have, in recent years, been some steps taken to control the humidity in the casting and melting room. This, of course, is an expensive operation and many years will pass before this becomes common practice, if ever. The natural formation of moisture in combustion products can be overcome to a great extent by proper design and application of burner equipment, so that the flame itself does not upset the surface of the bath and break the oxide coating which is naturally formed on the bath. The oxide coating formation on the bath, we have always believed, is helpful and acts as a deterent to gas absorption if not broken.

Hydrogen rate of absorption depends a great deal upon the alloying elements used in the aluminum. Magnesium alloys, for example, have considerably more desire for hydrogen absorption than non-magnesium alloys.

Dissolved hydrogen can be satisfactorily removed from molten aluminum by the application of certain tried and proved techniques.

FLUXING ALUMINUM

Dry nitrogen and chlorine are the most effective fluxing agents utilized on aluminum. When using the latter, however, certain safeguards must be employed, since it is both toxic and corrosive. The method of fluxing is simply to bubble nitrogen or chlorine through the molten metal bath, thereby causing an artificial boil which tends to release the dissolved gas. It is the opinion of the author's company that the chlorine gas flux is the better of the two, and certainly requires less time to do a thorough fluxing job, even though precautions are required to prevent ill effects on the people working around the furnace.

POROSITY IN ALUMINUM

Porosity is the result of hydrogen and other gas pickup left in or expelled from the castings when they solidify. It has been more or less proven in the case of die casting that at least 50 per cent or more of the porosity in the die castings is due to air entrapment in the die itself when pressure and chilling occur to form the casting. The nature of the casting process, except in the vacuum-casting technique itself, does not allow for the air in the die to escape completely. This air is trapped in the casting along with the hydrogen. In examining castings made with the vacuum-casting process, and those made with normal casting processes, it is quite evident that porosity in die casting is, to a great extent, caused by air entrapment. Hydrogen gas that is trapped has been placed under great pressures and, therefore, has been forced into more or less minute pockets. There is no chance for release of this gas. Excessive porosity and blistering becomes evident only when the casting is put under considerable heat for testing or for plating purposes.

Permanent-mold and sand castings are cooled much slower than die castings and, therefore, the tendency exists for the hydrogen gas to evolve from the molten metal as the casting solidifies. From a visual inspec-

tion standpoint this leaves porosity evident immediately and, therefore, greater care is required to insure gas-free molten metal when casting permanent molds and sand castings as compared to die castings.

Good housekeeping, of course, is the only solution for keeping buildup, formed at the metal line in refractory-lined furnaces, from entering the molten bath. The author's company believes the avoidance of entrapment of oxides is a matter of good access to the interior of the furnace and good operating control. The stillness of the bath, of course, is a great aid in allowing oxides to float on top, or deposit on the bottom of the furnace, leaving the molten metal clear of oxide. The company has noted that segregation appears to be a factor of chilling of the bath.

When a bath of molten metal is chilled by feeding an ingot into the bath, there is a tendency for the heavier alloying elements to segregate. The best solution to the segregation problem is to use holding furnaces and charge them with hot metal. Temperature control of the molten metal, of course, is another important function, which must be closely watched in order to prevent segregation.

ALUMINUM MELTING FURNACES

Unlike the zinc die-casting field, the aluminum permanent-mold and die-casting fields have a great many more varieties of furnaces available for use in melting and holding operations. Operations generally consist of separate holding furnaces at the machine, combination melting and holding furnaces at the machine, and separate melting-furnace equipment for hot-charging or pigging operations. There is a variety of furnace types available. They may be divided into three general classifications.

1. Indirect fired furnaces, muffle type, gas or oil fired.
   a. Iron-pot furnace with exterior flue for exhausting combustion gases.
   b. Crucible furnace with exterior flue for exhausting combustion gases.
2. Direct fired furnaces, gas or oil fired.
   a. Crucible furnaces, not sealed in—combustion gases passing over the bath.
   b. Single chamber reverberatory furnaces of the non-stack charging type.
   c. Single-chamber reverberatory furnaces of the stack charging type.
   d. Double-chamber melting and holding furnace.
   e. Continuous type dry hearth melting and holding furnace.
3. Electric furnaces.
   a. Electric induction furnace.
   b. Electric resistance refractory lined single-chamber furnace.
   c. Electric resistance crucible and iron-pot furnace.

IRON-POT FURNACE

Temperatures involved in melting and holding aluminum are anywhere from 1020 F on up to approximately 1600 F. While these operating temperatures are somewhat higher than those utilized for zinc, the iron-pot furnace has proven very satisfactory in aluminum die-casting operations.

The iron-pot furnace was one of the earliest utilized in the aluminum die-casting and permanent mold field. The many new furnace innovations which have since been introduced on the market, however, have, to a wide extent, replaced the iron-pot furnace.

The iron-pot furnace is different from any other furnace design on the market. First of all, the iron pot and the molten metal are all supported on the refractory lining side walls of the furnace. The crucible furnace, reverberatory furnace, and induction furnace all support the pot and/or metal load on the hearth of the furnace. Second, the iron-pot furnace incorporates considerably more combustion space than crucible melting furnaces. Depending upon the crucible furnace design, generally a space of 4 in.-7 in. is left underneath the crucible. A base block, of course, is used to support the crucible and must be approximately 4 in.-7 in. high. In the iron-pot furnace design, the space under the iron pot generally varies from 10 in.-15 in. and no supporting base block is required. The space around the pot, that is, between the pot and the side walls of the furnace, is also much more generous than that used with the crucible furnaces.

Heat conduction through an iron pot is much more rapid than through a crucible furnace, therefore, the heat input requirement of an iron-pot furnace is somewhat less than that required for a crucible furnace.

Iron-pot furnaces generally incorporate an exterior flue to vent the combustion gases. In addition, good iron-pot furnace design would utilize a split steel ring cover on top of the furnace, including rest pins for the steel pot. The steel cover protects the refractories from abrasion when alloying and ladling. The division of the steel cover into several sections allows room for the cover to expand and contract under temperature changes involved.

The rest pins, which are generally 3/8-in.-1/2-in. high, depending upon the size of the furnace, raise the pot sufficiently to allow for uniform flow of heat on the underside of the flange of the pot. If this flow of heat is not allowed to take place, stresses are set up in the pot due to uneven temperatures, and earlier pot failure than normal may well be the result.

Iron-Pot Life

Iron-pot life, when melting in an iron-pot furnace, will vary, depending upon the care given to the pot and to the cleaning of the furnace. The pot should be cleaned thoroughly and regularly so that buildup is not allowed to remain at the bottom. Such buildup, if allowed to remain, acts as an insulation, and sooner or later the underside of this section of the pot becomes overheated because it cannot transfer its heat as rapidly to the inside of the pot. Overheating of the bottom section of the pot sets up stresses and strains which cause early cracking and failure of the pot.

In recent years, iron pots have been aluminized to prevent oxidation. As I understand it, the coating on the outside has generally added to the pot life. Coating of the inside of the pot is also good protection and should be done regularly with washes available.

A third aid in obtaining optimum pot life is to keep the burner ports, hearth, and side walls of the furnace clean at all times. Any deflection can cause

the flame to play on the pot, which will cause a hot spot and early pot failure.

Pots should be repositioned at least once a week so that the relation of the burners is changed, and no one section of the pot remains in one position to receive the constant brunt of a possible hot flame. Flame adjustment is of utmost importance. Combustion products should be on the slightly reducing side at all times. An oxidizing flame will rapidly oxidize the iron pot and reduce pot life. In analyzing flue gases, no oxygen should be present. Depending upon the original gas analysis, the CO_2 content will approximate 10 per cent-11-1/2 per cent. CO should be less than 1 per cent for proper atmosphere control.

Pot life is variable in all plants. Some die casters set a time limit, at which time they pull the pots, regardless of condition. This is done in hopes of avoiding pot failure when a full charge of metal is in the pot. Others inspect the pot regularly, which should be done regardless of procedure, and use the pot until it reaches a certain stretch point and/or a certain thinness of wall section. On melting applications, two months pot life is not uncommon.

If an iron-pot furnace is used at the die-casting machine, strictly for holding purposes, and is properly cared for, pot life should approximate three to four months.

Gas Pilot And Nozzle Care

One item of concern which has been noted in most die-casting plants is the poor care given to gas pilots. Pilots are left hanging on the furnace in any fashion, and the pilot flame is allowed to play on the furnace shell, burner plate, and gas-air piping system. The flame is generally over-generous which causes, first of all, a waste of gas fuel. Second, the destruction of burner nozzles, burner plates, and shell sections is extremely high. Working conditions around the furnace are considerably warmer, much more dangerous to the operator, and a continual fire hazard is present.

A second item of concern on gas- and oil-fired furnaces is improper maintenance of the burner port and the uncleanliness of the burner nozzles. When burner ports are not properly maintained, gas can get behind the refractory lining between the shell and the lining itself and start to burn. This causes a hot spot on the shell, early failure of the shell, and still more severe damage to the rest of the furnace refractory lining.

Slag Hole And Flue Care

Slag holes and flue sections receive considerable flame erosion and must be kept in good repair. The iron pot should be removed from the furnace at least once every week so that burner ports, flues, and slag holes can be cleaned, checked, and repaired. Cracks in the refractory lining itself should also be patched. Burner ports which have restrictions reduce the flow of gas and upset combustion conditions, in addition to diverting the flame itself directly to the pot or some spot on the refractory lining.

Furnace life and refractory life is excellent when good maintenance is practiced.

While the author has seen refractory linings fail in a year or less, this is due, in most cases, to negligence. With good maintenance practice there is no reason why refractory life should not be in the neighborhood of two to three years. Still longer life has been experienced.

There is no excuse for furnace shell failure. Burner nozzles, however, are made of cast iron and are under more or less constant heat. These will tend to erode and deteriorate and should be replaced on the average of once a year. The nozzle opening size should be checked during routine patching. If the opening changes very much, it affects the vacuum which senses the amount of gas and air pulled through the mixer.

Zero Governor Care

Another part of the burner equipment which needs attention from time to time is the zero governor. This governor has a neoprene diaphragm in it which acts to zero the governor. The diaphragm tends to dry out from the heat. When leakage of gas is noted it must be replaced with the main burners shut off.

Many different size pots are used in the die casting industry. There has never been any standardization on pots. Consequently, furnaces were built around existing pot patterns. Furnaces have been developed for many different pot sizes, however, standard lists of iron pots generally cover only those which have found the widest acceptance. If the precise pot you plan to use is not listed in any of the manufacturer's bulletins, this does not mean that it is not available. Ask the manufacturer to quote you on a furnace to fit the pot dimensions. I am sure he will be able to supply you with a suitable furnace.

Fuel Consumption

Fuel consumption, of course, varies with the size pot used. The larger the pot capacity, the better the fuel consumption. Iron-pot furnaces are generally designed to turn over their bath approximately once every three hr when used as a melting and holding furnace, therefore, the hourly output of an aluminum iron-pot furnace will approximate one-third its bath capacity. When melting and holding, for example, a 600 lb aluminum bath capacity pot should turn over approximately 200 lb of aluminum per hr. In die-casting operations, a heel is generally left in the pot to rebuild the bath, except when the furnace operation is approaching the end of the day and the furnace is to be drained.

These furnaces are generally set up for a maximum BTU input of 3,000 BTU's per lb of melting capacity. In actuality only 80 per cent of this input is required. The remainder of 20 per cent is used to give you a quick startup when building up the bath from a cold furnace. For strictly holding furnace operations, we generally figure on 40 per cent of the input used for melting, which would be 1200 BTU's per lb of metal held. In actuality, fuel consumption during holding operations would fall between 750 BTU's and 1,000 BTU's per lb.

Metal losses in iron-pot furnaces, when melting ingot, approximate 1 per cent. When melting gates and risers, and scrap castings, these losses would be increased slightly and would approximate 2 per cent-3 per cent. Flashings would introduce a still higher

loss approximating 8 per cent-10 per cent. The overall loss, when melting die casting returns and ingot, would approximate 3 per cent-4 per cent.

Various considerations determine the type of furnace utilized. If an alloy is being run where iron pickup is a problem and iron tolerances are very low, considerable care must be taken to prevent iron pickup. This can be prevented partially through proper use of special coatings on the iron pots or by use of crucible or refractory-lined furnaces. In the case of high magnesium alloys which are prone to silicon and gas pickup, special refractories low in silicon or special coatings are required.

While iron furnaces were used almost exclusively at the start of aluminum die casting and permanent molding, the shift has been away from these pots, due to greater iron control requirements. Iron-pot furnaces are still used extensively and are an economical method of operation from the standpoint of initial investment and operating cost.

For many years the smelter has purposely kept the iron content of aluminum alloys very low so as to allow for some iron pickup when melting in iron pots, and still keep the alloy in proper ratio as far as iron content is concerned. In recent years when iron-pot furnaces have not been used and consequently no iron pickup has occurred, this reduced iron content in the alloy has created some difficulty. Iron content held within the proper range is helpful and in many cases necessary. It has been necessary for some die casters using non-iron-pot furnaces to add a slight amount of iron so as to raise the iron content of the original alloy.

CRUCIBLE FURNACE

The crucible furnace was brought into use because of iron pickup, fluxing operations, and higher temperature applications. This furnace design offers the same flexibility that the iron-pot furnace offers, in that alloy changes are made easily by changing pots should contamination be a problem. In addition, crucibles can be used on all aluminum alloys. In the case of pure aluminum the crucibles are generally given a special alumina spun coating, although this is not an absolute necessity. This is an excellent furnace for holding purposes, and in many cases for melting and holding (the latter especially on magnesium alloys where gas pickup tendencies are available and considerable fluxing is required).

Operating Costs

The cost of operation is somewhat greater than that of iron-pot furnaces. Fuel consumption would be approximately 20 per cent greater. Initial furnace cost is somewhat greater, and crucibles are slightly higher in initial cost. Crucible replacement cost is a little higher than that of iron pots.

Crucible output is generally one-third of its bath capacity when used as a melting and holding furnace. When used as a strictly holding furnace, it can turn over its bath as many times as you wish, as long as the metal being brought over is held close to casting temperatures.

Crucible life, when used in holding operations, would approximate three-four months. When used for melting and holding, life expectancy will decrease to 30-60 days. Actual fuel consumption when melting in a crucible would approximate 2800 BTU's per lb. Holding operations would require one-third to one-half of this amount per lb of metal held. Muffle-type furnaces generally add 15-20 min to a heat of metal, as compared to a non-muffled crucible-furnace operation.

Crucible and iron-pot furnaces have certain limitations in size and output. In addition, iron-pot and crucible replacements are always with you. In order to gain greater economy, therefore, from the standpoint of crucible replacement versus refractory lining life, and from the standpoint of fuel consumption, the reverberatory furnace was introduced into the field of melting and holding.

REVERBERATORY FURNACE

These furnaces first took the form of small reverberatory furnaces of 300 lb bath capacity and then kept on growing. They proved their worth immediately in savings of approximately one-third to one-half in fuel consumption. Operating costs on some permanent mold jobs were cut by 60 per cent when considering pots, fuel, direct labor, and indirect labor

Casting quality was still maintained and rejects were not increased over previous melting operations.

The iron-pot and the crucible furnaces have their place and it is not the intention to attempt to replace them except where it is to the advantage of the user to use other methods. The large tonnage of hot metal has grown to such an extent in many plants that it has been necessary to find faster, cheaper, and more convenient methods of melting, with an equal or better product. The reverberatory method is meeting that challenge and is widely accepted by most of the large melters.

Operating Costs

The reverberatory furnace is the least expensive method known for melting as the flame and products of combustion come in direct contact with the solid and molten metal. This, of course, was and is widely criticized by many melters. It has been a widely accepted theory that molten aluminum when exposed to a direct flame or the gases created by it would result in a pickup of these gases by the hot metal.

Nothing is more erroneous than the above theory; in fact, a controlled-combustion atmosphere is one of the most satisfactory methods of protecting the molten bath of aluminum when properly applied. There is a great deal to be learned but enough is known to establish the reverberatory furnace as a most satisfactory and economical method of producing high-grade, gas-free, close-grained, clean castings.

We believe there are other factors of control that will greatly relieve or completely eliminate porosity. Experiments conducted in our own plant indicate that metal previously preheated to below the melting point (approximately 900 F) before charging eliminates an important source of porosity. The moisture and gas absorbed by the cold metal are driven off by the heat before it is submerged in the molten bath, and part, at least, of the causes of porosity in the metal is due

to charging cold metal (room temperature) into the molten metal carrying with it moisture and absorbed gases.

Control Factors

Having built hundreds of reverberatory furnaces which are in use all over the country, the author's company has naturally come in contact with many of the best metallurgists and compared notes, and learned a great deal by doing so; for example, two factors were brought out by a prime producer of ingot and castings. First, that aluminum will pick up gas in direct proportion to the temperature to which it is raised regardless of how it is melted, and that about 1400 F is maximum to which it can be heated before the danger point. Second, that molten aluminum rapidly picks up gas in excess of this temperature and in direct proportion, and to avoid this pickup the metal should be cast at as low a temperature as possible.

For a jobbing foundry, this is a difficult matter to control for it is up to them to produce the best casting possible from the part design and the pattern submitted. In the captive foundries, a great deal can be done by closer co-operation between the foundry and the engineering department to design the casting in such a way that it can be cast at a temperature not in excess of 1400 F without losing any of the effectiveness of the part.

A third factor which cannot be ignored is the protective oxide coatings formed on the bath of molten metal. This coating, if not readily disturbed, acts as a protective coating against gas pickup.

STACK-CHARGING REVERBERATORY

The stack charging reverberatory can be a stationary furnace from which the metal is either tapped out into a ladle for transfer purposes or dipped from wells constructed on the sides of the furnace. These furnaces are made in sizes from 500 lb-15,000 lb capacity. Actually, they could be made larger if the demand existed. They are generally rectangular in shape with the burner equipment located at the front of the furnace and the exhaust flue and/or charging stack at the rear. Underneath the burner equipment at the front of the furnace is a large door which can be used for charging especially fine materials that need puddling. This door opening is also used for skimming and fluxing the metal.

The flue at the rear has a dual purpose. It is not only an exhaust opening for the furnace but is used for charging the regular run of the material, such as ingots and returns from the foundry. This provides a convenient and rapid method of charging the furnace. The charging is done while the burner equipment is in operation. There is no door to open and the furnace can be charged at any time, continuously if desired.

In the furnace proper or the combustion chamber, the bath of metal is carried at a depth approximating 1 ft. This metal is permitted to pass through openings in the side walls to reservoirs or dipout wells located on the sides of the furnace. The metal in these wells remains at approximately the same temperature as the metal in the combustion chamber. It is always available for ladling out and for casting purposes. In the event the castings are large and a large quantity of metal is required, there is a tapping spout on the side of the furnace so that the metal can be drained out into a transfer ladle. The furnace is cool to work around and the operator is not subjected to excessive temperatures.

The roof is generally of the bung-arch type; that is, the brick is held in place by clamps which are provided with springs on each end to allow the brick to expand and contract with the change of temperature in the furnace. The bungs can be lifted off for repairing the furnace or lining. In some cases, a suspended roof is utilized. In starting up each morning it is necessary to preheat the furnace approximately 45 min, after which time the metal is charged through the stack or exhaust flue until the bath of metal is approximately 1 ft deep. After the bath has been established and has reached casting temperature, a continuous supply of hot metal is available throughout the day, by charging the furnace at the same approximate rate metal is taken away.

Furnace Use

These furnaces are used by all types of foundries such as sand casters, permanent mold, die casters, and smelters. It is one of the most popular furnaces, and one of the most inexpensive methods of melting and handling aluminum in large quantities. It can be automatically controlled; as a rule a controlling pyrometer is used to indicate and control the metal temperature in one of the dipout wells.

It is an excellent furnace, if a continuous supply of metal is desired for the sand foundry, permanent-mold or die-casting plant, for supplying hot metal to the holding furnaces, or should you wish to remelt scrap and cast it into ingot. Melt rates are available from 150 lb to approximately 5,000 lb per hr.

Tilting Furnace

A similar furnace design is available in the form of a tilting furnace of the stack-charging type. This furnace has all of the same economies and continuous melting and charging abilities. It has found its widest application in die-casting and permanent-omld plants as a centralized melter for melting ingot, and in-plant scrap returns. The tilting furnace, however, is made in sizes of 1,000 lb on up to 3,000 lb bath capacity. Melt rates vary from 800 lb-2,000 lb of aluminum per hr. The advantage of the tilting mechanism, of course, is in the pouring operation into transfer ladles.

In the case of either the stationary or tilting stack-type reverberatory melting furnaces, refractory life generally approximates 18 months to two years. Melting losses, when melting die-casting returns, approximate 3 per cent-4 per cent. When melting ingot, melt losses approximate 3/4 per cent-1 per cent. Fuel costs approximate 2,000 BTU's per lb or less. A reducing atmosphere is used at all times.

The stack-type charging furnace cannot be equalled in over-all economy. Direct and indirect labor is held to a minimum. While there is refractory lining maintenance and replacement, the lining is only 9 in. thick as compared to box-type reverberatory furnaces

which have 16 in.-18 in. linings; consequently, lining costs per lb of metal melted are held to a minimum. Large baths of metal are never held needlessly, and need never be held overnight. The furnace need not be kept under heat as is true in the case of many large box reverberatory furnaces.

DOUBLE-CHAMBER FURNACE

The rapid increase in the use of aluminum in recent years has necessitated better methods of melting and handling of the metal than employed in the past; there are many models or designs, and the double chamber furnace is one of them.

This furnace is the result of a great deal of study and experimental work in the plant and in the field, working with plants that specialize in casting aluminum. The furnace was developed to meet known conditions and peculiarities of aluminum alloys regardless of how it is cast, whether in sand, permanent mold, die cast, or reclamation.

Porosity Causes

It is the opinion of the author's company that one of the principle causes of porosity in castings is due to submerging either cold, or room temperature metal, into a molten bath. Unless the metal is thoroughly dry, it will have moisture on the surface, generally referred to as capillary moisture. This moisture is carried into the bath, resulting in porosity. The two-chambered furnace completely eliminates this possibility.

Another cause of porosity in castings is overheating of the bath. This can take place in any type of furnace whether it is of the reverberatory type, crucible, or iron pot. Overheating is not a function of the type of flame used. Somewhere around 1400 F and over, aluminum picks up gas rapidly and the foundryman should do everything possible to cast aluminum at temperatures below this point, if he is after gas-free castings. It may of necessity require changes in the pattern or design.

It is the opinion of the author's company that a certain amount of dross, at least a small amount, in the holding furnace is beneficial. However, this dross must be of a certain type; it must be dry and not a glossy or wet type. The holding chamber in this double-chamber furnace provides a dry, fluffy type dross. With the above in mind, this two-chamber furnace was developed to eliminate the moisture in the metal before it is melted, to prevent overheating of the molten bath, to provide the proper type of dross covering over the metal in the holding furnace and, also, to eliminate hot charging in permanent mold and die casting plants.

Aluminum Heat Content

Figure 1 shows the heat content of aluminum. From this, you will note about 90 per cent of the heat required to bring aluminum up to a casting temperature is in the melting; not after it is in a molten stage. You will note further from this chart that it requires abou 450 BTU's per lb to bring solid metal up to the liquid state at a temperature of slightly over 1200 F; to raise it to approximately 1350 F, a normal permanent mold casting temperature, it requires only about 50 additional BTU's. From this, it was reasoned that the melting of aluminum is a two-furnace proposition; one to break it down and one to hold it, with each function having its own individual burner equipment of the proper size.

In a one-chambered furnace, it is necessary to have burner equipment 8-9 times greater than actually required after the metal is up to a casting temperature. Burner equipment usually does not have turn-down possibilities to hold the metal at the casting temperature without over-shooting metal temperatures.

Melting And Holding Furnace

You will note from a cross-section drawing (Fig. 2) of the double-chamber furnace that it is composed of two separate furnaces combined in one complete unit—one section is for holding the metal after it has been melted or broken down and the other is for melting only. In the melting furnace there is no bath. The flame is allowed to surround the material completely, and drive out the moisture before it melts. It then runs into the holding furnace.

It has been found that the metal will flow into the holding furnace at a temperature between 1160 and 1180 F. This is below the temperature where there is danger of gas pickup.

One of these chambers is always automatically controlled to eliminate the human element. The metal in the holding furnace can be controlled within 10 F due to the fact that it is constantly fed from the melting furnace with a molten metal charge at a constant temperature. Since uniform temperature is often of such great importance, it is necessary that the holding chamber be controlled; the melting chamber may be controlled automatically or manually. The author's company believes it best to use high-limit temperature controls on the melting chamber to prevent overheating of the refractories.

Another desirable effect developed, which was not considered at the time this furnace was developed, is that it eliminated hard spots in the molten bath because no chilling action takes place. It can be held day in and day out in the holding furnace without ill effect. Since it requires so little fuel to hold it overnight, in many cases it is desirable to do so

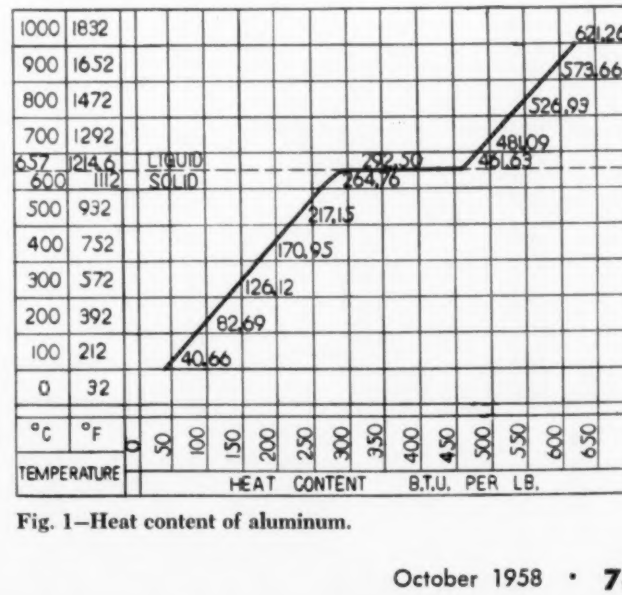
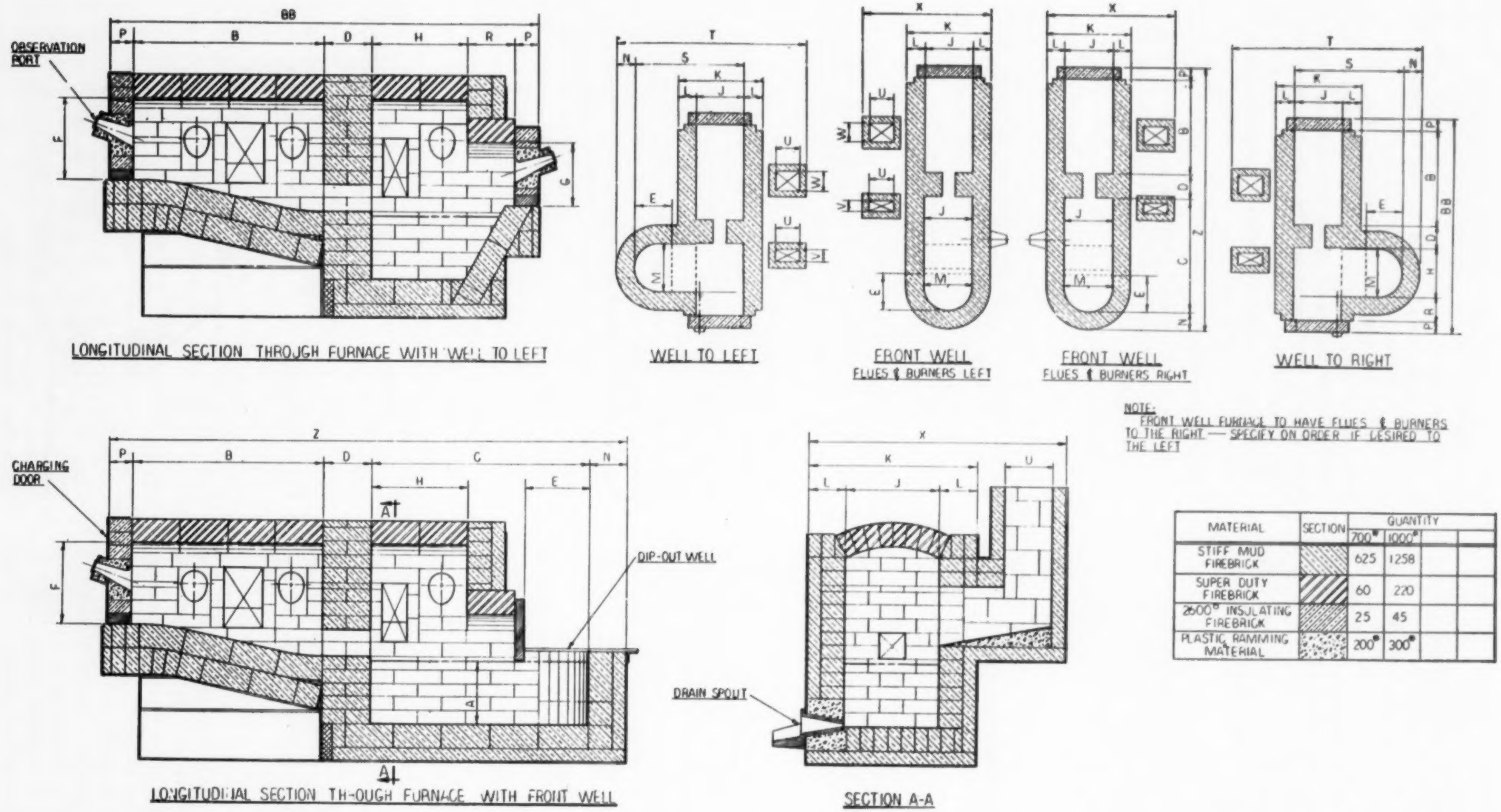


Fig. 1—Heat content of aluminum.



Furnace Size, lb	Melting Chamber Area, Sq. Ft.	Melting Rate lb Per Hr: Sq. Ft.	Melting Rate lb Per Hr: Total	Capacity, lb: Holding Chamber	Capacity, lb: Dip-out Well	Capacity, lb: Total	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Z	BB
700	4.2	100	420	610	250	860	1-0	3-0¼	3-7½	0-9	1-2	1-3½	1-0	1-6½	1-6	2-8	0-7	1-6	0-7	0-4½	0-9	3-5	6-0	0-9¼	0-4¼	0-6¾	4-1	8-4¼	6-9¾
1000	8.8	100	880	975	250	1325	1-0	3-10	3-9½	0-9	1-2	1-4¾	1-0	1-6½	2-4	3-10	0-9	1-6	0-7	0-4½	0-11	4-5	7-2	0-9¼	0-4¼	0-9¼	5-3	9-4	7-9½

(Columns A through BB: SECTIONAL DIMENSIONS, ft.-in.)

Fig. 2 — Detailed cross-section dimensional drawing of a double-chamber furnace combined in one complete unit, showing also materials used in furnace construction. Consult table for dimensions of various parts shown.

rather than to tap out the metal, cast it into ingot, and start all over again in the morning. This, of course, provides the foundrymen with hot metal at the moment the foundry starts in the morning.

The hourly output of this type furnace is based on the hearth area of the melting chamber. The larger the hearth, the greater the yield. In the standard furnace, a holding chamber of approximately twice the hourly yield of the melting hearth has been provided on this furnace; in other words, a furnace having a bath capacity of 700 lb has an output of about 400 lb per hr inasmuch as this is the amount of metal that can be melted per hour in the melting chamber.

Temperature Control

The reason for having a bath with twice the hourly yield is to insure a constant temperature. The metal in the bath is raised from 100-200 degrees over the temperature of the metal entering it, in the case of permanent mold and sand casting, and it must be large enough to absorb this difference and remain constant.

This furnace is very desirable, particularly in permanent-mold and die-casting foundries, as it completely eliminates hot charging (in which metal is brought over from a breakdown furnace and poured into the holding furnace). It also does away with the possibility of contamination by getting metals mixed up in a melting room inasmuch as the returns can be remelted immediately after they are cast in this double-chamber furnace. There is no transporting them back to a breakdown furnace and back again to the holding furnace. It does away with the possibility of picking up gas in transferring metal from a breakdown furnace to a holding furnace.

This furnace is fired with either oil or gas or combination burner equipment; however, the author's company prefers gas. It should be operated with a rich flame; that is, with a reducing flame in order to eliminate oxidation. This is done by a simple adjustment of the proportional mixer.

The furnace is not intended for melting anything but solid material, either ingot or returns from the foundry, but not for light material such as chips, clippings, or borings. This has to be done in a furnace in which this material can be submerged.

Remelting Rejects

There is one other very desirable feature, particularly to the die caster and permanent-mold foundry; rejected castings containing inserts can be remelted in this furnace. The metal is sweated off of the insert and the insert can be raked off the hearth through the charging door. It has been attempted, in this furnace, to unite a complete unit, to eliminate as much handling as possible, to overcome past difficulties encountered in other types of melting, and to produce the finest possible castings both chemically and physically.

Fuel input is on the order of 1,500 BTU's per lb of metal melted and 500 BTU's per lb of metal held. Actual consumption is somewhat less than this. Refractory lining life will vary from one to two years depending upon the care taken in good maintenance and cleaning. Metal losses, of course, also depend on good practice of operation. Metal losses of 3/4-1 per cent have been noted on the hearth when melting ingot and solids. Dross losses in the holding chamber generally vary from 1-1/2-2 per cent, half of which is recoverable from the dross.

Bridgewall life between the holding and melting chamber has been the major difficulty in earlier models. Since then the double-chamber furnace has been redesigned into two separate furnace units which are combined similar to the earlier design. That is, metal flows directly into the holding chamber from the melting hearth. While the latest furnace has only had a couple of years experience behind it, there are definite signs of increased refractory life and possibly still less dross loss in the holding chamber. Other factors have remained on a more or less par basis.

NON-STACK CHARGING FURNACE

The non-stack charging reverberatory melting furnace would be a box-type reverberatory charged through the doors or through scrap charging wells. This furnace comes in sizes from 5,000 lb on up to 100,000 lb. It has found wide acceptance in casting of extrusion billets, rolling mill slabs, smelter plants, recovering of chips, and in some permanent-mold and die-casting plants as centralized melting units where large quantities of metal are required.

While this furnace design is excellent and has a good metal recovery, the author's company believes that for most die-casting and permanent-mold applications it is an expensive method of operation. Melting rates are low per sq. ft of hearth area. For example, a 10,000 lb box reverberatory has a melt rate of approximately 30 lb to the sq. ft and a hearth area of approximately 50 sq. ft. The melt rate is 1,500 lb per hr and it has a bath of metal that must be held in the ratio of approximately 6 to 1 compared to the melt rate.

The stack charging type reverberatory furnace has a melt rate of approximately 4 times that of the box reverb. A 5,000 lb stack-charging furnace will melt 3,000 lb per hr requiring approximately half of the floor space.

Despite the slightly higher melt loss of the stack reverberatory furnace which would be 3-4 per cent as compared to 2 per cent for the box reverberatory when melting die-casting and permanent-mold returns, the stock-charging furnace is still more economical. Less labor is required to operate a stack-charging furnace, fuel consumption is somewhat less and considerably less metal must be held in a stack-charging furnace as compared to a box-type furnace. Lining replacement in a stack-charging furnace is also considerably less per lb of metal melted.

ELECTRIC-RESISTANCE FURNACE

Electric-resistance iron-pot crucible and refractory-lined-type furnaces have recently appeared on the market for holding applications. These furnace types have come into the picture not to compete with iron-pot or crucible furnaces, but to compete with electric-induction furnaces. All three furnaces produce working conditions around the furnace which are exceptionally cool and compare favorably to elec-

tric-induction furnaces. Other advantages were also considered important in the refractory-lined electric-resistance-type furnace because they represent substantial savings in operating cost, as follows, when compared to electric induction furnaces:

1. There are no channels to plug up.
2. In the event of any power failure the metal can freeze up and be remelted without damage to the furnace.
3. Downtime would be held to a minimum.
4. Replacement of electric resistance elements can be made in a matter of minutes.
5. The furnace is easy to skim and keep clean.
6. Dross formation is held to a minimum.
7. Metal bath is held quiet, therefore insuring a clean bath, no oxide mixing in molten metal, and consequently a high quality metal and minimum of rejects.
8. Temperature control is excellent with no overshooting of metal temperatures.
9. Lining life will be greatly prolonged, and it is believed possible three years minimum would not be uncommon.
10. Lining replacement is simple as compared to electric induction furnaces.
11. Furnace operation is noiseless for all intents and purposes.
12. Electrical failure is generally confined to the replacement of an occasional electric resistance element, and not a whole induction coil and refractory lining.

Furnace Construction

Furnace construction is simplified. Furnace space requirements are held to a minimum. Electrical circuits and equipment are so uncomplicated that an average electrician can maintain and operate it. Electric resistance elements are protected by bars so that they do not get damaged when cleaning the furnace. The features built into this furnace design hold forth, therefore, a means of creating most favorable working conditions and low operating cost.

The above features would also apply to the iron-pot and crucible electric-resistance furnaces; however, in these cases you would have the added cost of iron pots and crucibles. In addition, kw power consumption would be slightly higher in crucible and iron-pot furnaces because heat transfer to the metal must be made through these mediums rather than directly.

ELECTRIC-INDUCTION FURNACE

The author's company believes that for aluminum holding purposes, that the electric-resistance furnace offers an excellent furnace design. This design also offers an initial cost savings over electric-induction furnaces. Working conditions are comparable to electric-induction furnaces. Metal losses are comparable to induction furnaces. Electric power requirements are closely on a par in the refractory-lined type with a possible slight favor going to the induction furnace. Power costs, however, are more than offset with the savings in operating features outlined above.

The electric-induction furnace has been sold on the basis of low temperature working conditions and minimum melt losses. The initial cost is high compared to any other furnace on the market, for similar melt rates and holding capacities, in the gas or oil fired line or electric resistance line. Another claim of electric-induction furnace manufacturers is the agitation feature which tends to bring alloy in solution and to eliminate segregation.

CONCLUSIONS

The author's company believes that every piece of equipment has its place, where when properly applied, it can excel over other types of equipment. There are certain places in the country where power costs are favorable to the consumer. In these cases, power must be weighed against gas or oil to see which offers the most economy.

During the past 10 years, economy considerations in many cases have gone out of the window. The only problem was to get the castings or finished product out to the customer, figure your cost, and then to price the product so that a profit could be made. This day may soon come again, but the day of reckoning with costs is upon us.

Actually, we do not begin to check costs in earnest until necessity forces such a decision upon us. We should, however, always check costs. This practice keeps our profits at the highest point in both good and bad times, whether prices are low or high. It always keeps us in a competitive position and reflects itself in greater profits.

The main difference in operation between gas and electric furnaces is that in the case of gas-fired furnaces you only pay for the fuel you actually use. In electric furnaces you pay for the power you use plus the demand load charge which is determined by the maximum power usage at any one time during the month. This demand load can be determined in 1 min or 1 sec of your monthly operation. For example, should you have three 100 kw electric furnaces in your plant and all three furnaces are turned on for 1 min drawing the full current load, and then shut off and not used again all month, the demand load would be 300 kw times $1.70-$1.90 per kw.

Therefore, regardless of how much use you make of the furnaces for the next 30 days you will have a demand load cost of $510.00-$570.00 established. Current use for actual operation of the furnaces beyond this point would be in the neighborhood of 1.08 cents per kw hr additional. Great care must be exercised, therefore, in the use of electric furnace equipment, if power costs per lb of metal melted and held are to remain at the lowest point obtainable based on metal demands for the month.

Still Bath vs. Stirring Action

There has always been considerable controversy between the benefits of the still bath and a continuous stirring action. The argument on the part of the induction-furnace manufacturer has been that the stirring action prevents segregation of alloys.

The author's company feels, from actual experimentation, that segregation of alloys is due to a chilling action taking place in the molten bath. The chilling action is caused by charging cold ingot and returns into the bath. It is also known that no chilling

action takes place when molten metal is added to a bath of metal in lieu of cold metal. Experience has borne out that little or no precipitation takes place in the bottom of a double-chamber holding furnace.

The author's company has always advocated a still bath because with a still bath a minimum amount of metal surface is exposed for oxidation. In addition, the oxide surface coating is not broken and acts as a protection against gas absorption. In addition, a still bath is required to maintain proper separation of oxides from the molten metal inasmuch as the specific gravity of metal and oxides is very close.

It appears, therefore, by stirring a bath of metal, such as is done in electric-induction furnaces, more and more surface is exposed for oxidation, the oxide surface coating is broken allowing for greater gas absorption, and oxides are merely churned into the metal and are not allowed to segregate.

For the above reasons many die-casting and permanent-mold plants melt only ingot in the electric-induction furnaces at the die-casting machine. Scrap returns are generally remelted in a centralized melt area and the metal is pigged and recharged at the diecasting machine in the form of pig. Segregation caused by chilling, of course, is automatically offset by the continual stirring action of the current.

Advantageous melt rates advertised must, therefore, be carefully weighed against power consumption, demand load, remelt operation, and maintenance of the furnace equipment. The prominently advertised stirring action also helps to plug the channels in the electric-induction furnaces; constant care, therefore, is required to keep these channels open. Electric power failure can cause a channel to freeze solid with aluminum and in some cases requires a complete relining of the furnace. In addition, a prolonged power failure will cause the electric-induction coil to burn out because the fan cannot operate to keep this coil cool.

One new aspect coming into the picture on aluminum die casting is vacuum die casting itself. This field opens up a new possibility of siphoning metal from the holding furnace into the die-casting machine itself. Should the siphoning system be adopted throughout industry, whether vacuum casting is utilized or not, it offers considerable possibilities, the author's company believes. Such a vacuum system will throw greater stress on holding-furnace equipment only at the die-casting machine in order to maintain the cleanest and highest quality of metal at the machine and, therefore, to obtain the least amount of scrap and the highest quality of casting.

This means that most holding-furnace applications would be hot charged with molten metal either from a dry-hearth melting unit or by means of transfer ladles from large melting furnace equipment. This innovation, of course, will gradually affect the entire die-casting industry and, the author believes, there will be a slow shift toward vacuum die casting as time goes on.

EFFECT OF IMPURITIES UPON THE RESISTANCE OF MAGNESIUM CASTING ALLOYS AZ92 AND AZ63 TO CORROSION

By

B. J. Nelson*

ABSTRACT

The paper covers the effect of higher maximum amounts of impurities upon the properties and resistance to corrosion of AZ92 and AZ63 casting alloys. Included in the corrosion tests were accelerated tests in NaCl-H_2O_2 by alternate immersion and in 3-1/2 per cent NaCl spray, as well as various atmospheric exposures.

Some natural aging occurs in sand cast AZ92 and AZ63 alloys. The resistance to corrosion of alloys having the same range of impurity content is comparable, but the presence of nickel leads to inferior resistance to corrosion. The influence of deliberately added nickel in influencing the resistance to corrosion is developed over a range of environments and exposures.

INTRODUCTION

In 1945, the author's company initiated a program of corrosion testing on the magnesium casting alloys AZ92 and AZ63, which are the lower purity versions of AZ92A and AZ63A. Table 1 shows the composition limits for all of these alloys. The differences in composition are reflected in higher maximum amounts of silicon, nickel, and other impurities for the alloys of lower purity.

Silicon increases would be expected to decrease the tensile strength and the elongation of AZ92A or of AZ63A alloy, but to have little effect upon the resistance to corrosion. Copper, on the other hand, would not be expected to have an effect upon resistance to corrosion when it is present in conjunction with the amounts of zinc which are normally present in these alloys. The impurity of the greatest concern in these alloys is nickel, which substantially decreases the resistance to corrosion of magnesium alloys.‡

It was decided that nickel would be added deliberately to these alloys in order to study its effect on resistance to corrosion. In the course of the investigation, the effect of the impurities was followed by visual examination, and by tests, to determine property losses after various corrosive exposures and property changes upon natural aging.

MATERIAL

The material used in this investigation consisted of sand cast test bars of AZ92A alloy and of AZ63A alloy of normal composition; sand cast test bars of AZ92 and of AZ63 of low, of intermediate, and of high nickel content; permanent mold cast bars of AZ92A alloy of normal composition; and permanent mold cast bars of AZ92 alloy having low, intermediate, and high nickel contents. AZ92A and AZ63A alloys were included as comparison or "control" alloys.

All alloys used were within the composition limit ranges; the nickel content (deliberately varied in this test) ranged from 0.001 per cent-0.040 per cent so that a substantial composition range was available.

All test bars were tested in four tempers: -C, -T51, -T4, and -T6. In addition, bars from each temper were further differentiated; one group was given an acid dip after casting for cleaning the surface, while another group was given the chrome-pickle treatment. The acid-dip consisted of a 10-sec immersion in 8 per cent HNO_3 + 2 per cent H_2SO_4 in water. A total of 2,160 test bars was included in this test and each value for corrosion losses, etc., is an average of three bars.

PROCEDURE AND RESULTS

The tests which were carried out included the following:

1) Tensile tests initially and after 10 years of natural aging.
2) Tensile tests after alternate immersion in salt-peroxide solution for 96 hr.
3) Tensile tests after intermittent salt spray test (3-1/2 per cent NaCl) for periods of up to 24 weeks.
4) Tensile tests after exposure in the unstressed condition to the marine atmosphere of Point Judith, R. I., for a period of over 7 years.

TABLE 1 – COMPOSITION LIMITS FOR MAGNESIUM CASTING ALLOYS

Alloy	Al	Zn	Mn, Min.	Si, Max.	Cu, Max.	Ni, Max.	Others, Max.
AZ92A	8.3-9.7	1.7-2.3	0.10	0.3	0.25	0.01	0.3
AZ92	8.3-9.7	1.7-2.3	0.10	0.5	0.25	0.025	0.8
AZ63A	5.3-6.7	2.5-3.5	0.15	0.3	0.25	0.01	0.3
AZ63	5.3-6.7	2.5-3.5	0.15	0.5	0.25	0.025	0.8

‡Hanawalt, Nelson and Peloubet, A.I.M.E., *147*, 273 (1942).

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TABLE 2 – CORROSION TESTS MADE ON MAGNESIUM CASTING ALLOYS

Alloy	Type	Ni Class	Properties Tested, Time		Corrosion Tests Made				
					A.I. $NaCl-H_2O_2$, hr.	NaCl Spray, wk.	Point Judith, yr.	New Kensington, Exam. yr.	Miami Tide Water, mo.
AZ92A	S.C.	Low	11/45	4/56	96	12	7.2	8	..
AZ92	S.C.	Low	11/45	4/56	96	12	7.2	8	..
AZ92	S.C.	High	11/45	4/56	96	12	7.2	8	..
AZ92	S.C.	Low	4/50	4/56	..	24	1.10	4	1
AZ92	S.C.	Inter.	4/50	4/56	..	24	1.10	4	1
AZ92	S.C.	High	4/50	4/56	..	24	1.10	4	1
AZ63A	S.C.	Low	11/45	4/56	96	12	7.2	8	..
AZ63	S.C.	Low	11/45	4/56	96	12	7.2	8	..
AZ63	S.C.	High	11/45	4/56	96	12	7.2	8	..
AZ63	S.C.	Low	4/50	4/56	..	24	1.10	4	1
AZ63	S.C.	Inter.	4/50	4/56	..	24	1.10	4	1
AZ63	S.C.	High	4/50	4/56	..	24	1.10	4	1
AZ92A	P.M.	Low	11/45	4/56	96	12	7.2	8	..
AZ92	P.M.	Low	11/45	4/56	96	12	7.2	8	..
AZ92	P.M.	Low	4/50	4/56	..	24	1.10	8	1
AZ92	P.M.	Inter.	4/50	4/56	..	24	1.10	4	1
AZ92	P.M.	High	11/45	4/56	96	12	7.2	8	..
AZ92	P.M.	High	4/50	4/56	..	24	1.10	4	1

5) Tensile tests after exposure to the individual atmosphere of New Kensington, Pa., for 8 years.
6) Tensile tests after exposure to Miami, Fla., tide water for one month.

The list of tests which were made is given in Table 2.

Tables 3 and 4 show the composition and the properties as well as the corrosion losses for the alloys tested in this program. Specimens were photographed at various stages of all the corrosion tests, but only selected, representative groups are reproduced here. All these corrosion tests and their results will be discussed.

The tensile strengths of the sand cast and permanent mold cast AZ92 and AZ63 alloys are decreased and the yield strengths are increased by the order of 2,000-5,000 psi by the higher copper and silicon content of these alloys, but the added nickel has little, if any, effect upon the tensile properties. This is more readily apparent when considering these alloys in the -T4 temper. For the group of alloys having no appreciable variation in copper or silicon but having a low, intermediate and high nickel content, there is no substantial variation in properties with nickel content.

The degree of natural aging occurring in these alloys is small but probably does exist. For the permanent-mold cast alloys, the evidence of natural aging is less convincing. The properties of AZ92 alloy are lower than the properties for AZ92A alloy. In addition, the permanent-mold cast alloys seem to show some decreases in tensile properties during the period of natural aging. Wherever natural aging did occur, it seemed to be confined to the -C, -T51, and -T4 tempers, and the properties of the alloys in the -T6 temper are decreased slightly by natural aging.

After exposure to the salt-peroxide solution and salt spray, the specimens were photographed and property losses obtained. Figure 1 shows the appearance of some of the sand cast alloys after a 12-week exposure to the intermittent salt spray. After the salt-peroxide and salt spray tests were made, the following conclusions were drawn: AZ92 and AZ63 alloys have about the same resistance to corrosion as AZ92A and AZ63A alloys of the same nickel content, but when

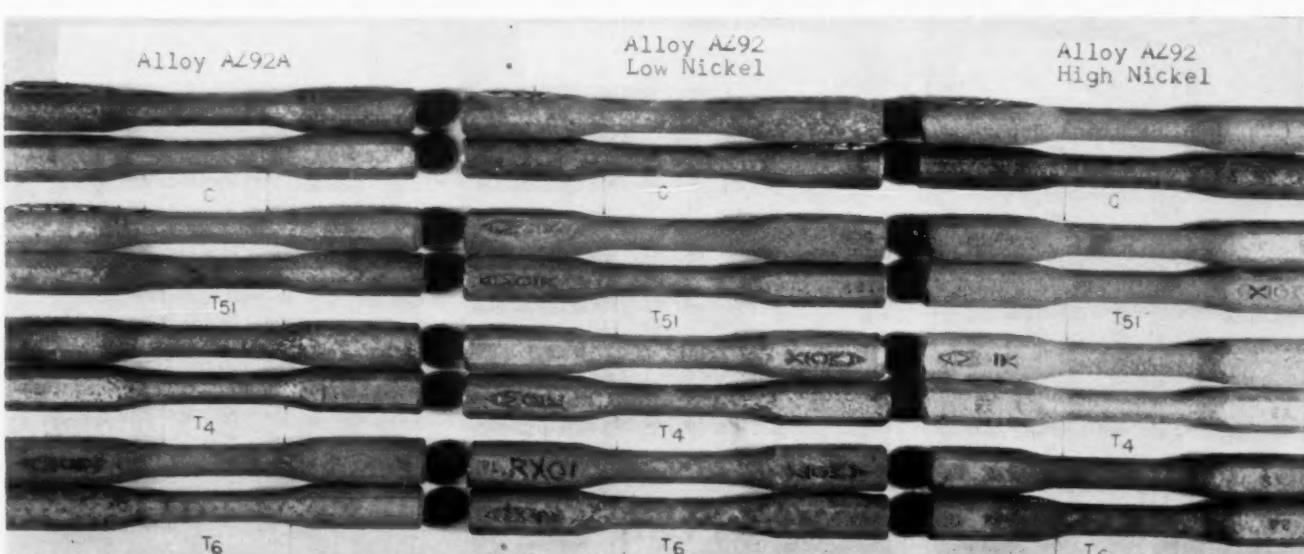

Fig. 1 – Appearance of sand cast magnesium alloys after 12 weeks exposure to intermittent 3-1/2 per cent NaCl spray. Top specimen in each group of two was acid-dipped; bottom specimen received acid-dip plus chrome-pickle.

TABLE 3 – NATURAL AGING & RESISTANCE TO CORROSION OF MAGNESIUM ALLOY CAST TEST BARS

			% Composition				Initial Properties[1]							% Change by Corrosion					
							Tested 11-45			Tested 4-56			Surface	Alt.-Immer.[2] $NaCl\text{-}H_2O_2$ 96 hr		Int. 3-1/3% NaCl Spray 12 weeks		P.J. Atmosphere 7.2 Years	
S. No.	Type	Alloy	Si	Cu	Ni	Temper	T.S.	Y.S.	El.	T.S.	Y.S.	El.	Treatment	T.S.	El.	T.S.	El.	T.S.	El.
88276	S.C.[3]	AZ92A	0.23	0.04	0.001	C	25400	14800	2.0	24500	14000	1.7	Acid Dip[4]	-26	-15	-6	-15	-13	-41
													AMC-A	-26	-40	-5	-10	-9	-41
88277	S.C.	AZ92A	0.23	0.04	0.001	T51	24100	16200	1.2	24900	17000	1.7	A.D.	-23	-17	+4	+25	-1	-41
													AMC-A	-21	-17	-2	0	-6	-41
88278	S.C.	AZ92A	0.23	0.04	0.001	T4	39600	14200	12.7	40300	18300	11.0	A.D.	-54	-61	+1	-13	-16	-25
													AMC-A	-34	-47	-8	-21	-11	-31
88279	S.C.	AZ92A	0.23	0.04	0.001	T6	38300	22000	3.2	38800	20400	3.0	A.D.	-35	-59	-1	-47	-2	-23
													AMC-A	-17	-69	+3	+9	0	-23
88280	S.C.	AZ92	0.48	0.26	0.001	C	23400	16500	1.7	23800	16100	1.3	A.D.	-28	-41	-5	-41	-11	-46
													AMC-A	-21	-29	+5	+76	-11	-8
88281	S.C.	AZ92	0.48	0.26	0.001	T51	23700	18400	1.2	24400	18800	1.2	A.D.	-28	-19	-11	-33	LH[6]	LH
													AMC-A	-12	-17	+3	0	-12	-17
88282	S.C.	AZ92	0.48	0.26	0.001	T4	38600	16100	9.7	36300	17900	6.5	A.D.	-57	-59	-13	-35	LH	LH
													AMC-A	-51	-54	-7	-14	+1	+23
88283	S.C.	AZ92	0.48	0.26	0.001	T6	37500	23100	2.7	36700	21000	2.3	A.D.	-32	-63	+4	+11	LH	LH
													AMC-A	-12	-19	+6	-7	-4	-26
88284	S.C.	AZ92	0.40	0.25	0.040	C	23700	16000	1.7	23800	15300	1.7	A.D.	-84	—[5]	+3	-29	LH	LH
													AMC-A	-78	—	+5	-41	-62	-71
88285	S.C.	AZ92	0.40	0.25	0.040	T51	27600	18900	1.8	26500	18100	2.0	A.D.	-71	—	-10	-61	LH	LH
													AMC-A	-69	—	-13	-44	-51	-85
88286	S.C.	AZ92	0.40	0.25	0.040	T4	37100	15700	9.7	40500	18600	10.2	A.D.	-88	—	-6	-25	-22	-80
													AMC-A	-82	—	-5	-20	-16	-80
88287	S.C.	AZ92	0.40	0.25	0.040	T6	41200	23400	3.0	36000	22800	2.7	A.D.	-68	—	-2	-32	-58	+122
													AMC-A	-66	—	-5	-33	-53	+96
88288	S.C.	AZ63A	0.012	0.02	0.001	C	27300	12600	4.0	30300	15200	5.0	A.D.	-37	-75	+4	0	-11	-16
													AMC-A	-11	-25	+2	+5	-12	-30
88289	S.C.	AZ63A	0.012	0.02	0.001	T51	28600	16200	3.8	27900	16100	4.2	A.D.	-38	—	0	-16	-3	-21
													AMC-A	-24	-55	+8	-3	-9	-33
88290	S.C.	AZ63A	0.012	0.02	0.001	T4	40800	14300	14.8	42600	18500	13.2	A.D.	-35	-39	+4	-12	-6	-7
													AMC-A	-32	-41	0	-9	-5	-9
88291	S.C.	AZ63A	0.012	0.02	0.001	T6	42800	20700	6.5	40300	19500	6.3	A.D.	-47	—	-9	-35	-9	-29
													AMC-A	-26	-54	-4	-23	-8	-32
88292	S.C.	AZ63	0.015	0.28	0.002	C	26200	14900	3.0	27500	17500	2.8	A.D.	-19	-33	+4	-7	LH	LH
													AMC-A	-15	-50	0	-23	-10	-29
88293	S.C.	AZ63	0.015	0.28	0.002	T51	27500	17500	2.7	25900	17500	2.7	A.D.	-25	-63	-1	-26	LH	LH
													AMC-A	-14	-19	-2	-19	-5	-26
88294	S.C.	AZ63	0.015	0.28	0.002	T4	37900	15600	11.0	40000	20900	8.3	A.D.	-35	-38	0	-18	LH	LH
													AMC-A	-26	-45	+5	-7	-8	+2
88295	S.C.	AZ63	0.015	0.28	0.002	T6	37300	22300	2.7	38600	21400	4.5	A.D.	-36	—	+2	0	-8	-33
													AMC-A	-17	-26	+3	-7	-7	-29
88296	S.C.	AZ63	0.58	0.29	0.025	C	25200	14100	2.5	26000	15500	2.3	A.D.	-37	+72	-1	-12	LH	LH
													AMC-A	-30	+117	+2	+8	-23	+9
88297	S.C.	AZ63	0.58	0.29	0.025	T51	26500	17200	2.3	25500	15500	2.7	A.D.	-55	—	-2	-4	-23	-26
													AMC-A	-44	—	-1	-13	-21	-44
88298	S.C.	AZ63	0.58	0.29	0.025	T4	38200	15400	9.3	36000	20200	5.7	A.D.	-61	—	-10	-27	-30	+9
													AMC-A	-63	—	-0	0	-30	+18
88299	S.C.	AZ63	0.58	0.29	0.025	T6	38100	22300	4.0	37300	21100	3.3	A.D.	-61	—	-1	-12	-14	-3
													AMC-A	-58	—	-1	-20	-22	-30
88300	P.M.[3]	AZ92A	0.05	0.02	0.001	C	26900	17200	2.3	27900	19100	2.2	A.D.	-18	-4	-3	-35	-7	-32
													AMC-A	-7	+87	0	-43	-4	-9
88301	P.M.	AZ92A	0.05	0.02	0.001	T51	27400	20400	0.7	28100	19600	1.2	A.D.	-10	+43	+2	-29	-5	+50
													AMC-A	-8	+71	+1	-29	-10	+33
88302	P.M.	AZ92A	0.05	0.02	0.001	T4	35700	17700	5.5	34400	20000	3.8	A.D.	-12	+22	0	+15	-10	0
													AMC-A	-3	-13	-8	-27	+13	+84
88303	P.M.	AZ92A	0.05	0.02	0.001	T6	42300	26100	0	37200	25600	0.8	A.D.	-11	—	-8	—	+8	+25
													AMC-A	-17	—	-7	—	+1	-38

TABLE 3 – (CONTINUED) NATURAL AGING & RESISTANCE TO CORROSION OF MAGNESIUM ALLOY CAST TEST BARS

S. No.	Type	Alloy	% Composition Si	Cu	Ni	Temper	Initial Properties[1] Tested 11-45 T.S.	Y.S.	El.	Tested 4-56 T.S.	Y.S.	El.	Surface Treatment	% Change by Corrosion: Alt.-Immer.[2] NaCl-H_2O_2 96 hr T.S.	El.	Int. 3-1/3% NaCl Spray 12 weeks T.S.	El.	P.J. Atmosphere 7.2 Years T.S.	El.
88304	P.M.	AZ92	0.46	0.30	0.001	C	23600	14900	0.8	23100	15100	1.0	A.D.	−5	+80	+3	−30	−2	+20
													AMC-A	−5	+30	−1	−70	−4	−30
88305	P.M.	AZ92	0.46	0.30	0.001	T51	25100	19700	4.2	23700	18800	0.3	A.D.	−11	+25	−8	−75	−1	+133
													AMC-A	−11	+25	0	−62	−3	+133
88306	P.M.	AZ92	0.46	0.30	0.001	T4	32300	16300	1.0	30200	18800	2.7	A.D.	−14	−17	−3	−29	0	0
													AMC-A	−8	−12	−4	−24	+7	+67
88307	P.M.	AZ92	0.46	0.30	0.001	T6	36500	25700	1.8	36100	23400	1.3	A.D.	−4	0	+1	+20	−5	−23
													AMC-A	−4	+20	+5	0	+1	−100
88308	P.M.	AZ92	0.45	0.27	0.024	C	25800	19000	1.8	25000	19600	0.7	A.D.	−68	—	−3	−44	LH	LH
													AMC-A	−53	—	−2	−44	−29	−71
88309	P.M.	AZ92	0.45	0.27	0.024	T51	25000	21000	1.0	24000	19800	0.7	A.D.	−58	—	−1	−50	LH	LH
													AMC-A	−44	—	−2	−50	−10	+14
88310	P.M.	AZ92	0.45	0.27	0.024	T4	30400	19100	3.5	30600	20400	2.5	A.D.	−61	—	−1	−14	LH	LH
													AMC-A	−39	—	−13	−14	−15	−8
88311	P.M.	AZ92	0.45	0.27	0.024	T6	36500	28100	7.0	32700	25700	0.7	A.D.	−67	—	−11	0	LH	LH
													AMC-A	−53	—	−3	−29	0	−100

1. Values are averages of 3 bars.
2. Alt. inner. Test–Solution contains 57 gm NaCl & 3 gr H_2O_2 per liter.
3. S. C. = Sand Cast, P. M. = permanent mold
4. A. D. = 10 sec. dip in 8 parts HNO_3, 2 parts H_2SO_4 & 90 parts H_2O. AMC-A = A.D. + AMC Treatment (Chrome Pickel).
5. Elongation not determined on severely corroded bars.
6. LH = Lost in Hurricane of 8-31-54.

New Kensington (data not available) exposures have been in test 10 years.

the alloys contain over 0.025 per cent nickel, the resistance to corrosion decreases.

It was further found that copper contents from 0.02 per cent-0.3 per cent and silicon from 0.05 per cent-0.6 per cent have no adverse effects upon the resistance to corrosion of the AZ92 and AZ63 alloys. The effect of iron content which ranged from 0.007 per cent-0.028 per cent, was probably masked by other factors so that it was not possible to adequately determine the effect of this range of iron contents.

A supplementary group of alloys containing low, intermediate, and high nickel contents was also tested in the different experiments. Figure 2 shows the appearance of a group of sand cast bars exposed 24 weeks to the 3-1/2 per cent NaCl intermittent spray. In general, the acid-dipped specimens show more general corrosion than do those given the chrome-pickle treatment. It is believed that this is due to the local breakdown of the chrome-pickle which leads to pitting, whereas the cleaned acid-dipped specimens corroded over-all generally.

NICKEL CONTENT VARIATION

Under the limits of the investigation it did not seem that a variation of nickel content from 0.001-0.04 per cent has any adverse effects upon the resistance to corrosion of AZ92 and AZ63 alloys in the intermittent salt spray test. However, it was found in these tests that nickel is more deleterious in decreasing the resistance to corrosion in the salt-peroxide test. The supplementary group mentioned before, containing low, intermediate, and high nickel contents, were tested in Miami tide water. After one month in this test they were examined, photographed, and tested. Figures 3 and 4 show the appearance of these items in AZ92 and AZ63 after the Miami exposure. From these figures there is no doubt about the effect of nickel in accelerating the rate of corrosion. The losses for these and previous specimens are given in various tables.

In some cases, the specimens of higher nickel content were too severely corroded to allow accurate measurement of the loss to be made. In this test, specimens having the acid-dip sometimes showed more severe corrosion than did those having the chrome-pickle. This result may reflect the initial protection given by the chrome-pickle before breakdown of the surface has begun.

Specimens were exposed at Point Judith, R. I., for periods ranging up to over seven years when a hurricane scattered the specimens about and buried many of them in wet sand. However, Fig. 5 shows the appearance of sand cast AZ92A and AZ92 alloys exposed four years to Point Judith, and Fig. 6 shows the appearance of premanent-mold AZ92A and AZ92 bars exposed to Point Judith for four years. In this test, AZ92 of high nickel content is inferior to AZ92 of low nickel content, which is in turn inferior to the base composition (0 per cent Ni).

In like manner, AZ63 of high nickel content is inferior to AZ63 of low nickel, which in turn is inferior to the base composition (0 per cent Ni). It seems that alloys in the -C and -T51 temper may be less resistant to corrosion than those in the -T4 and -T6 temper, but in this test there is little difference be-

TABLE 4 – RESISTANCE TO CORROSION OF MAGNESIUM ALLOYS AZ92 AND AZ63

S. No.	Alloy[1] and Temper	Method of Casting	Analyses, %[2] Al	Zn	Mn	Si	Fe	Cu	Ni	Tensile Properties: Average of Six Specimens Tested[3] T.S. psi	Y.S. psi	% El. in 2 in.	Specimens 13-15 Tested 4-10-56 T.S. psi	Y.S. psi	% El. in 2 in.	% Change by Corrosion of Unstressed Cast Tensile Bars: 24 wks. Int. 3.5% NaCl Spray, Acid Dip Spec. 1-3[4,8] T.S.	El.	AMC-A Treat Spec. 16-18[5,8] T.S.	El.	46 Months P.J. Atmosphere, Acid Dip Spec. 7-9[4] T.S.	El.	AMC-A Treat Spec. 22-24[5] T.S.	El.	1 Month Miami Tide-Water, Acid Dip Spec. 10-12[4,8] T.S.	El.	AMC-A Treat Spec. 25-27[5,8] T.S.	El.
130607	AZ92-C	S.C.[6]	9.10	1.93	0.23	0.43	0.019	0.22	0.001	23580	15280	2.0	23100	15600	1.7	–22	–75	–23	–45	L.H.[9]		L.H.		–17	–35	–11	–15
130608	-T4	S.C.	9.10	1.93	0.23	0.43	0.019	0.22	0.001	38520	14340	10.2	39100	16600	10.5	–17	–34	–24	–49	L.H.		L.H.		–24	–33	–13	–26
130609	-T51	S.C.	9.10	1.93	0.23	0.43	0.019	0.22	0.001	24500	17750	1.2	23700	17000	1.2	–18	–58	–28	–33	L.H.		L.H.		–17	0	–5	+8
130610	-T6	S.C.	9.10	1.93	0.23	0.43	0.019	0.22	0.001	39200	23700	2.3	40200	21800	3.3	–18	–43	–23	–45	L.H.		L.H.		–17	–43	+1	+28
130611	AZ92-C	S.C.	9.04	2.07	0.22	0.45	0.017	0.19	0.011	23010	16400	1.1	22700	15600	2.0	–14	–9	–14	–9	L.H.		L.H.		–17	–9	–5	+45
130612	-T4	S.C.	9.04	2.07	0.22	0.45	0.017	0.19	0.011	39170	13790	11.4	39800	16400	12.0	–17	–37	–15	–28	L.H.		L.H.		–21	–30	–9	–15
130613	-T51	S.C.	9.04	2.07	0.22	0.45	0.017	0.19	0.011	23160	17360	0.5	22500	16600	2.0	–14	*	–18	*	L.H.		L.H.		–16	+67	–10	+72
130614	-T6	S.C.	9.04	2.07	0.22	0.45	0.017	0.19	0.011	39660	23780	2.3	41700	22200	3.8	–18	–22	–3	–57	L.H.		–10	–42	–21	–26	–8	–13
130615	AZ92-C	S.C.	9.07	2.07	0.20	0.47	0.009	0.24	0.021	23620	15920	1.3	23800	15800	2.3	–6	0	–12	0	–25	–43	–22	–13	*	*	–37	–8
130616	-T4	S.C.	9.07	2.07	0.20	0.47	0.009	0.24	0.021	38380	13680	10.4	38800	16300	10.0	–15	–25	–12	–31	–21	–20	–18	–15	*	*	*	*
130617	-T51	S.C.	9.07	2.07	0.20	0.47	0.009	0.24	0.021	24390	17250	0.8	23900	16100	1.8	–12	*	–17	*	–20	–28	–12	–17	*	*	*	*
130618	-T6	S.C.	9.07	2.07	0.20	0.47	0.009	0.24	0.021	40520	22100	2.5	40000	20700	3.3	–11	–20	–10	–12	–10	–16	–8	–9	*	*	–49	–20
130619	AZ63-C	S.C.	6.34	3.18	0.25	0.39	0.008	0.26	0.001	26200	14640	3.7	27000	15500	4.2	–10	–38	–15	–32	–13	–24	–11	–12	–10	+3	–8	+3
130620	-T4	S.C.	6.34	3.18	0.25	0.39	0.008	0.26	0.001	38630	15000	12.1	39800	19200	10.2	–7	–21	–16	–44	–8	–2	–8	–7	–14	–31	–6	–17
130621	-T51	S.C.	6.34	3.18	0.25	0.39	0.008	0.26	0.001	26040	16070	2.4	26400	15500	3.7	–11	–29	–16	–50	–5	–5	–7	+8	–6	+27	–7	+27
130622	-T6	S.C.	6.34	3.18	0.25	0.39	0.008	0.26	0.001	37670	21370	4.3	38200	19600	5.0	–14	–30	–22	–53	L.H.		L.H.		–17	–37	–8	–14
130623	AZ63-C	S.C.	6.50	3.32	0.25	0.34	0.009	0.26	0.013	25510	12980	3.7	24600	13400	3.0	–4	+3	–9	–14	L.H.		L.H.		–17	–5	–1	+23
130624	-T4	S.C.	6.50	3.32	0.25	0.34	0.009	0.26	0.013	37020	13220	11.9	39400	18100	11.5	–4	–18	–10	–29	L.H.		L.H.		–16	–29	–11	–24
130625	-T51	S.C.	6.50	3.32	0.25	0.34	0.009	0.26	0.013	24640	13750	2.9	25100	13800	4.0	–10	–21	–12	+3	L.H.		L.H.		–16	+9	–4	+31
130626	-T6	S.C.	6.50	3.32	0.25	0.34	0.009	0.26	0.013	37260	18910	5.0	38400	18600	1.5	–14	–34	–18	–44	L.H.		L.H.		–17	–26	–12	0
130627	AZ63-C	S.C.	6.28	3.36	0.22	0.32	0.009	0.24	0.029	25000	13580	3.6	27500	15200	4.3	–9	–31	–12	–17	–21	–14	–20	–12	*	*	*	*
130628	-T4	S.C.	6.28	3.36	0.22	0.32	0.009	0.24	0.029	36700	13070	11.1	38300	17100	10.3	–6	–16	–13	–26	–20	–8	–18	–11	*	*	*	*
130629	-T51	S.C.	6.28	3.36	0.22	0.32	0.009	0.24	0.029	26060	16590	2.9	26500	14800	3.8	–9	–14	–13	–14	–14	–3	–14	–16	*	*	–35	+3
130630	-T6	S.C.	6.28	3.36	0.22	0.32	0.009	0.24	0.029	37330	19300	4.6	36800	18700	5.3	–16	–41	–19	–35	–16	–25	–14	–11	*	*	*	*
130631	AZ92-C	P.M.[7]	8.95	2.06	0.24	0.44	0.023	0.21	0.001	25500	16800	1.5	25900	17400	2.0	–12	–67	–13	–33	–7	–15	–8	–15	–14	+35	–6	+32
130632	-T4	P.M.	8.95	2.06	0.24	0.44	0.023	0.21	0.001	40500	16170	11.3	38400	16900	9.5	–14	–34	–16	–35	–5	–11	–6	–16	*	*	–13	–22
130633	-T51	P.M.	8.95	2.06	0.24	0.44	0.023	0.21	0.001	26540	18880	1.3	27000	18400	1.3	–14	–62	–14	–62	–8	+15	–8	+15	–13	+13	–9	+24
130634	-T6	P.M.	8.95	2.06	0.24	0.44	0.023	0.21	0.001	41340	25800	2.3	40800	23400	2.2	–16	–57	–22	–57	–9	–9	–4	0	–10	+8	–6	+15
130635	AZ92-C	P.M.	8.97	2.21	0.17	0.36	0.019	0.23	0.011	26960	17270	1.7	26800	17300	2.0	–10	–29	–15	–41	–9	+25	–8	+25	*	*	*	*
130636	-T4	P.M.	8.97	2.21	0.17	0.36	0.019	0.23	0.011	40660	16490	11.7	39900	19100	12.5	–11	–29	–13	–30	–12	–26	–14	–22	*	*	–8	–8
130637	-T51	P.M.	8.97	2.21	0.17	0.36	0.019	0.23	0.011	26510	19560	1.2	27600	18500	1.7	–2	–33	–12	–42	–9	–12	–10	–12	–30	*	–13	+40
130638	-T6	P.M.	8.97	2.21	0.17	0.36	0.019	0.23	0.011	41200	25150	2.3	41700	21900	2.7	–9	–48	–20	–48	–6	–15	–6	0	–9	–13	–12	–22
130639	AZ92-C	P.M.	9.04	2.02	0.21	0.45	0.015	0.23	0.020	26430	15560	2.5	27700	16400	3.0	–2	–8	–10	–40	–19	–27	–18	–27	*	*	*	*
130640	-T4	P.M.	9.04	2.07	0.20	0.44	0.012	0.23	0.022	40910	16060	12.6	41400	18100	11.8	–16	–42	–16	–39	–24	–31	–22	–30	*	*	–34	–21
130641	-T51	P.M.	9.04	2.02	0.21	0.45	0.015	0.23	0.020	27450	17780	1.3	27800	17800	2.0	–6	–23	–10	–23	–10	0	–8	0	*	*	*	*
130642	-T6	P.M.	9.04	2.07	0.20	0.44	0.012	0.23	0.022	42190	24730	2.7	39500	22300	1.5	–14	–52	–19	–63	–5	+67	–3	+80	*	*	*	*

1. -C = As Cast
   -T4 = Solution Heat Treated
   -T51 = Stabilized
   -T6 = Solution Heat Treated and Aged
2. Al, Zn, Mn, Si, Fe, Cu, and Ni analyses determined at Cleveland Plant unless otherwise noted.
3. Average mechanical properties obtained on six bars of each composition and condition at the Cleveland Plant. The approximate date of testing was February, 1950.
4. Specimen 1-15 inclusive, were acid-dipped, – immersed for 10 sec in a solution at room temperature containing by volume 8 parts of concentrated HNO_3, 2 parts of concentrated H_2SO_4 and 90 parts H_2O.
5. Specimens 16-30 inclusive, were acid-dipped then later chrome-pickled (AMC-A Treatment).
6. Sand Cast
7. Permanent Mold
8. * Indicates that the specimen was too severely corroded to permit accurate measurement of the value.
9. L.H. Lost in Hurricane of Aug. 31, 1954.

Acid dip Spec. 4-6, and AMC-A Treat. Spec. 19-21, exposed to N.K. atmosphere; no data available.

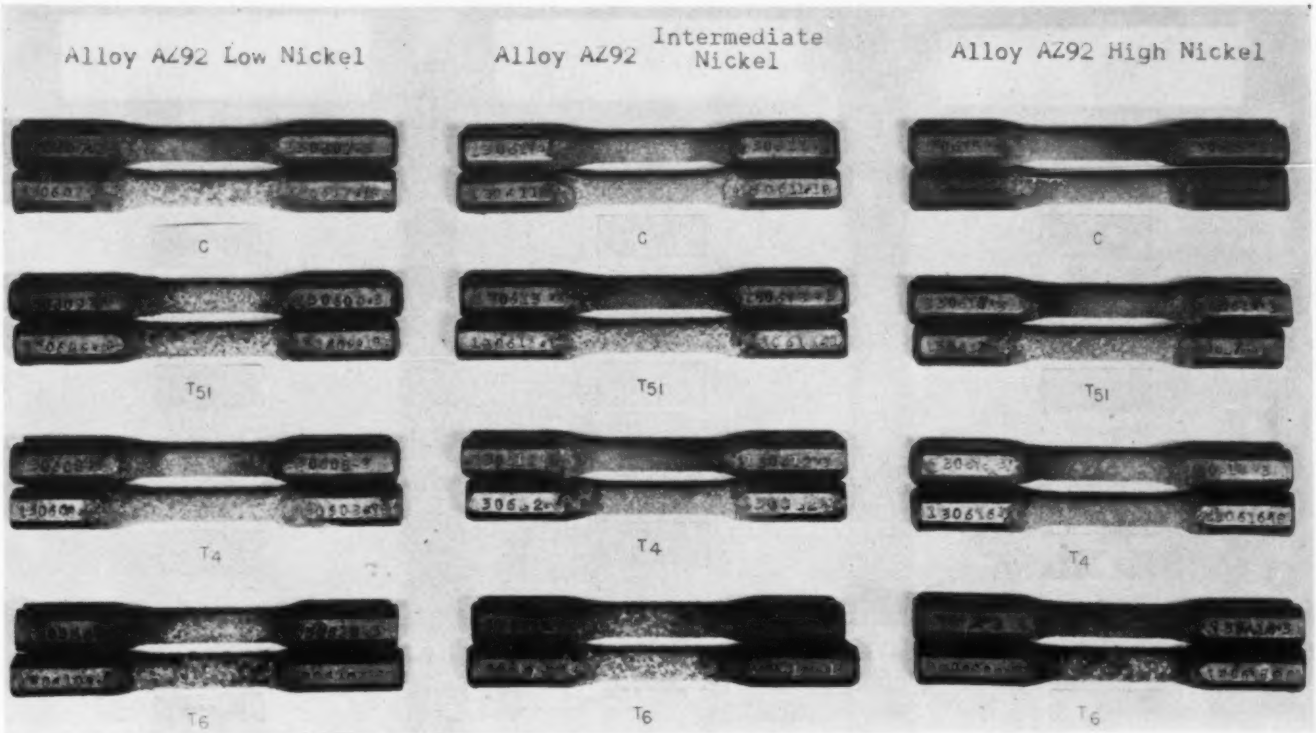

Fig. 2 – Appearance of sand cast alloys after exposure of 24 weeks to 3-1/2 per cent NaCl intermittent spray.

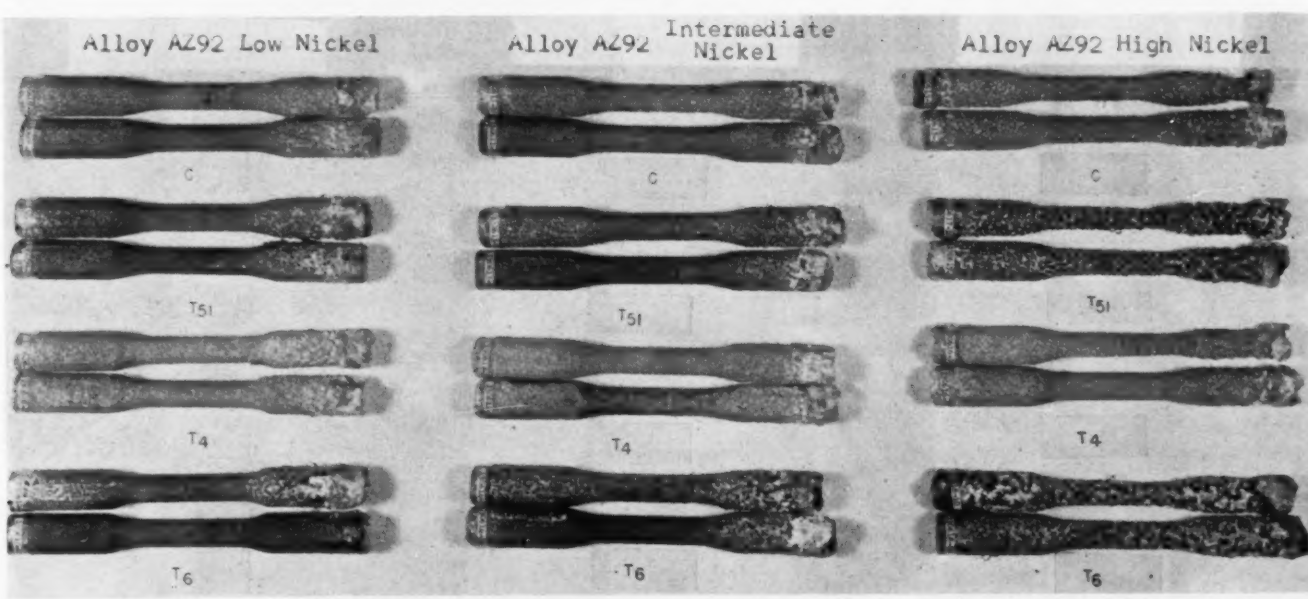

Fig. 3 – AZ92 sand cast bars exposed to tide water at Miami, Fla., for one month. Upper bar of each temper group given an acid-dip. Lower bar of each temper group given a chrome-pickle.

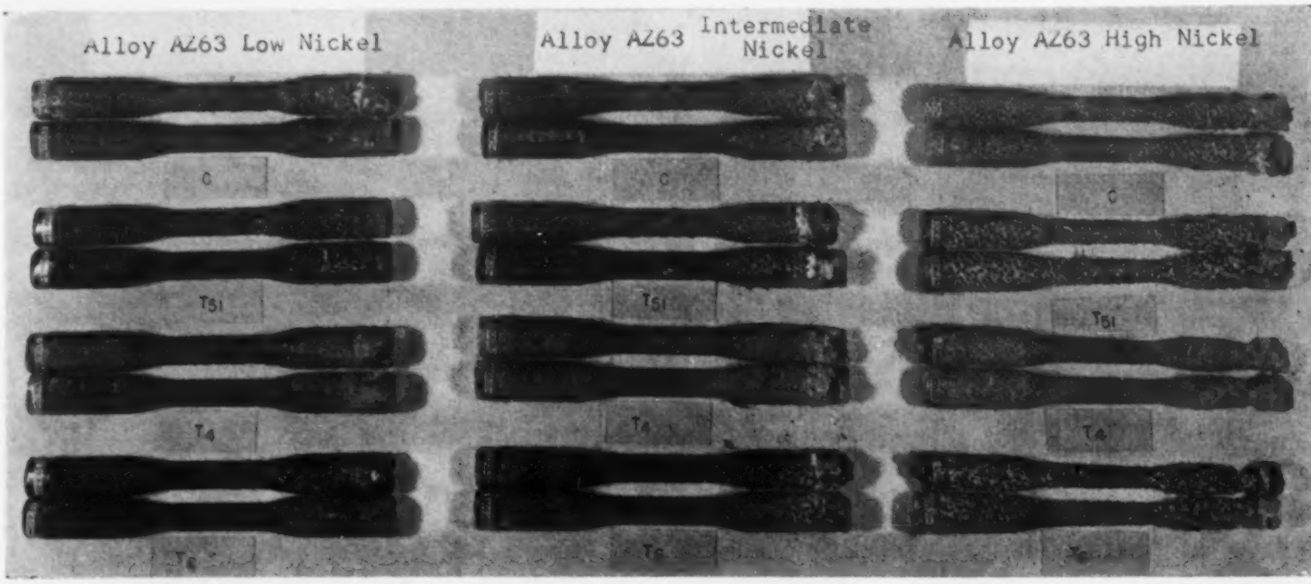

Fig. 4 – AZ63 sand cast bars exposed to tide water at Miami, Fla., for one month. Upper bar of each temper group given an acid-dip. Lower bar of each temper group given a chrome-pickle.

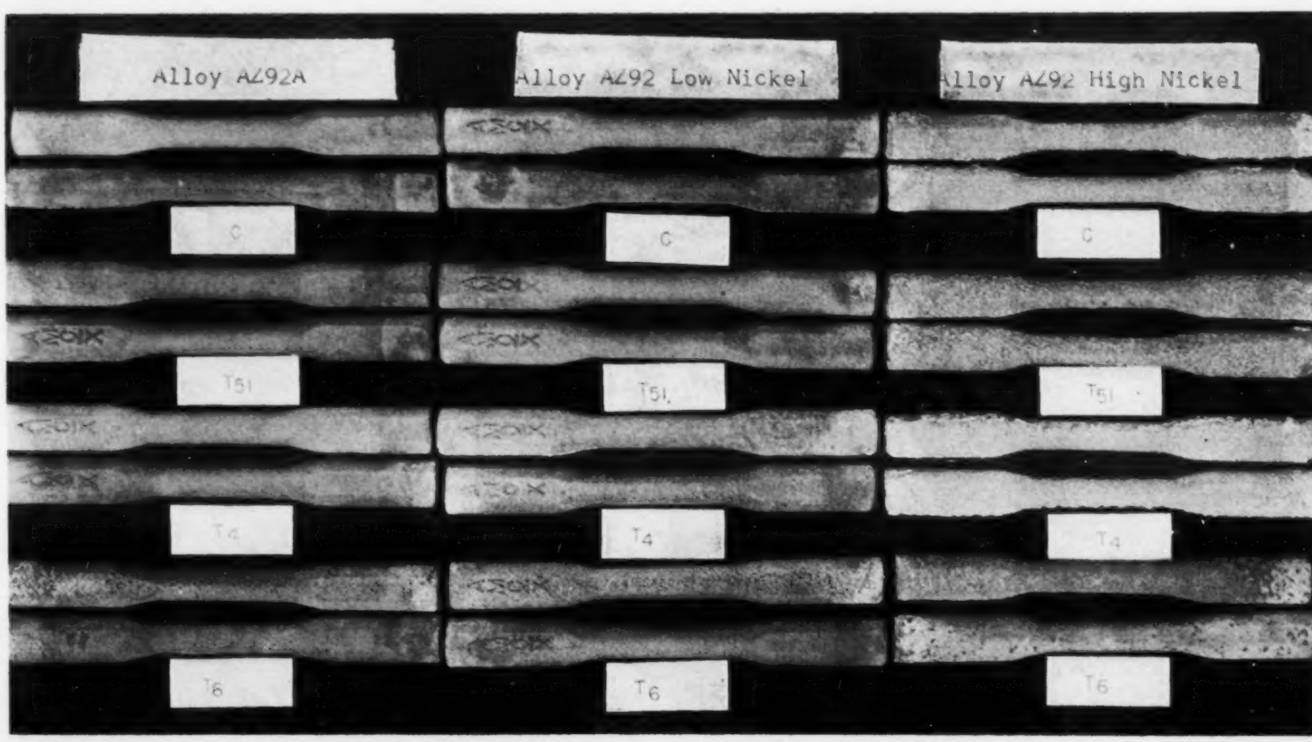

Fig. 5 – Appearance of sand cast magnesium alloys after exposure to Point Judith atmosphere for four years.

Fig. 6 – Appearance of permanent mold cast magnesium alloys after exposure to Point Judith atmosphere for four years.

tween the alloys in the acid-dipped or chrome-pickled condition. Where it was possible to make comparisons for the specimens exposed for a longer period, but subsequently buffeted by the hurricane, it was found that AZ92 and AZ63 alloys of low nickel content have roughly the same losses, but that the alloys of higher nickel content have substantially greater losses. The difference between the acid-dipped and the chrome-pickled specimens is roughly nil in these tests.

Specimens were examined after four years and after eight years exposure in the industrial New Kensington atmosphere. Figure 7 shows the appearance of sand cast AZ92A and AZ92 bars after eight years exposure to New Kensington atmosphere, while Fig. 8 shows the appearance of permanent-mold cast bars of AZ92A and AZ92 after similar exposure. In this test, all the groups of alloys appear similar, the attack ranging from superficial to mild but the alloys in the -T4 temper exhibit the most attack. Alloys of comparable nickel content but having other impurity limits have similar appearances after the exposure. The permanent mold bars appear better than the sand cast bars after this eight year exposure. There

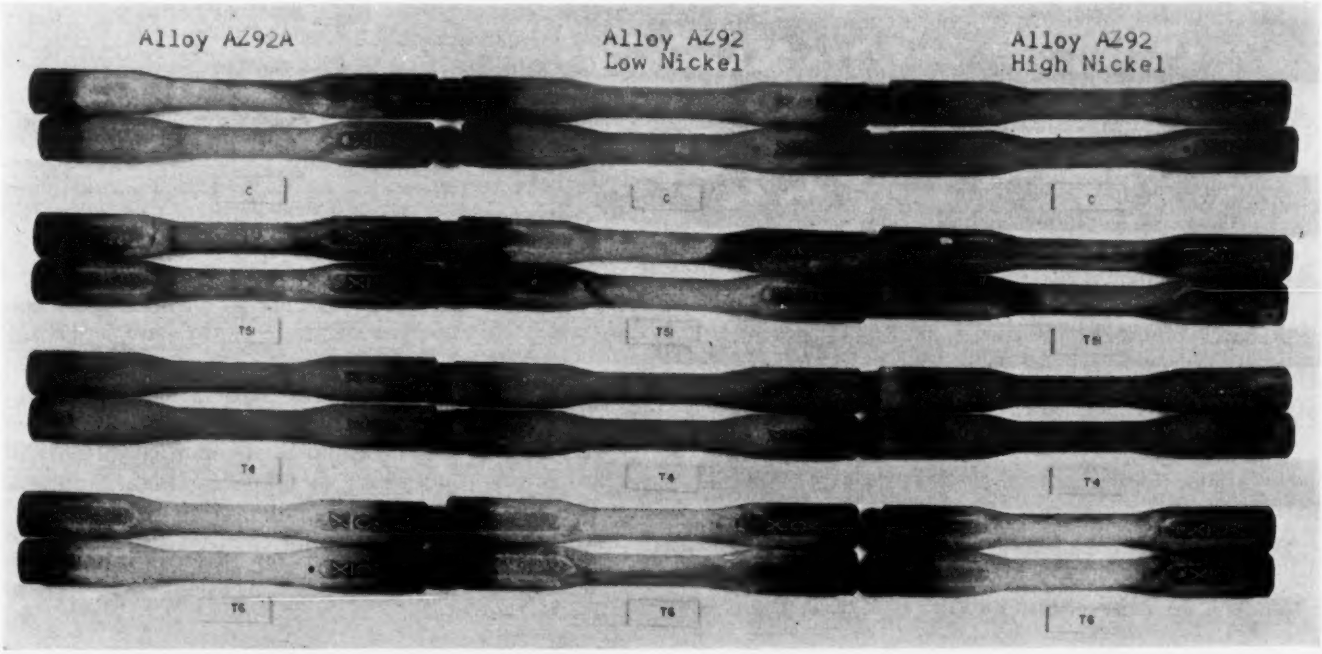

Fig. 7 – Appearance of sand cast magnesium alloy bars after exposure to New Kensington atmosphere for eight years. Top specimen in each group acid-dipped; others chrome-pickled.

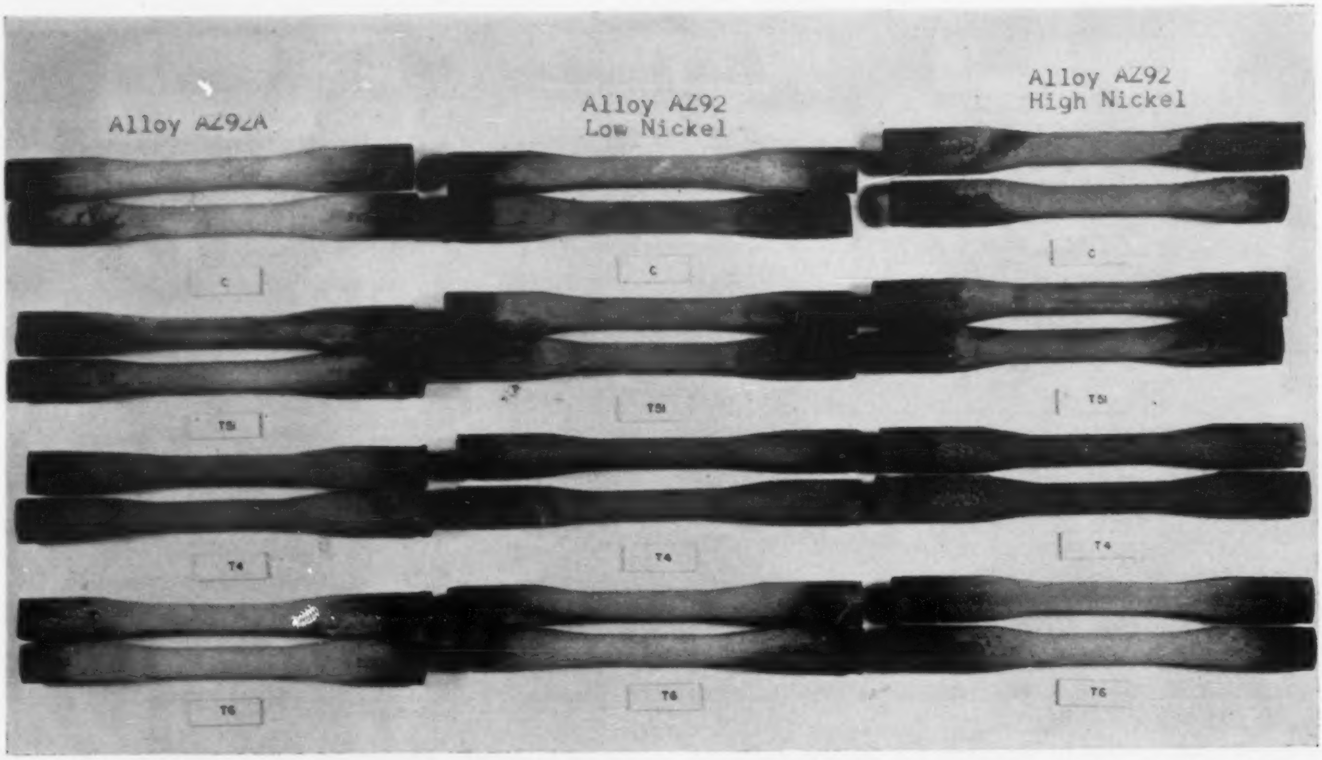

Fig. 8 – Appearance of permanent mold cast magnesium alloys after exposure to New Kensington atmosphere for eight years. Top specimen in each group acid-dipped; others chrome-pickled.

appears little difference between the acid-dipped and the chrome-pickled bars in these tests.

CONCLUSIONS

The following conclusions are based on property losses and on visual appearance:

1. The tensile strengths of the AZ92 and AZ63 alloys, where compared to AZ92A and AZ63A, are decreased slightly but the yield strength is increased somewhat by the additional amounts of copper and of silicon which are present in the AZ92 and AZ63 alloys; nickel has little if any effect on the properties.
2. Some natural aging occurs in sand cast AZ92 and AZ63 alloys; the evidence is less convincing for permanent mold cast AZ92. In addition, the properties of the alloys in the -T6 temper are decreased slightly by natural aging.
3. In NaCl environments, alloys having the same range of impurity content, including nickel, have about the same resistance to corrosion. The alloys of higher nickel content have greater losses, and in NaCl environments, permanent mold cast bars have a resistance to corrosion slightly superior to that of sand cast bars. The deleterious effect of nickel on these alloys is readily apparent when alloys are exposed to the NaCl-H_2O_2 test, or to the Miami tide water test.
4. In general, acid dipped bars are more resistant to localized corrosion than are chrome-pickled bars, as determined visually. This is, no doubt, due to the local breakdown of the chrome-pickle which then leads to a pitting attack. However, the loss in tensile strength following any exposure is usually higher for acid-dipped bars, indicating the over-all reduction of cross-section during the exposure.
5. Based upon exposures of up to seven years in a marine atmosphere (Point Judith, R. I.), all alloys of low nickel content have about the same resistance to corrosion; higher nickel contents lead to an inferior resistance to corrosion. In this test, the alloys in the -C and -T51 tempers may be less resistant to corrosion than are those in the -T4 and -T6 temper.
6. In an industrial atmosphere, the corrosion resistance of different groups of alloys of the same temper appear similar. There is little if any difference in this test between the overall atmospheric corrosion resistance of alloy bars which are acid-dipped or chrome-pickled. In this case, any breakdown of the chrome-pickled surface is slow, and a pitting type of attack does not seem to occur.
7. With the exception of alloys low in nickel content, the resistance to corrosion of alloys which contain greater amounts of impurities is comparable in an industrial atmosphere to alloys of higher purity. The alloys of low nickel content are superior to the same type of alloys having higher nickel content.

PARTICLE PACKING—PRINCIPLES AND LIMITATIONS

AFS Sand Division, Basic Concepts Committee (8-V)

Prepared By

G. J. Grott*

INTRODUCTION

Particle packing will be discussed according to these practices used in making structural bodies of aggregates:

1. Use of crushed material – all pieces retained.
2. Use of crushed material – some pieces rejected.
3. Use of natural deposits of small particles – with or without further preparation.
4. Blending or natural deposits, crushed materials, or fractions of either.
5. Simple graphs are used to present mathematical models describing particle packing in each of these practices.

USE OF CRUSHED MATERIAL—ALL PIECES RETAINED

Start with a single solid piece of material. Break it. Put the pieces back into their exact original positions relative to each other. In theory nothing will have changed. The shape and density will be the same.

In practice this has not yet been possible. It is extremely difficult even to know that all the pieces have been recovered. It is equally difficult to prove that no strange particles have been introduced.

However, let us follow such a putting together operation and record it in graph form. We will judge our success according to the attainment of the original shape and density as measured by the per cent voids in our built up structure. To make it easier, we will assume the foresight to have prepared a container of the exact dimensions of the original piece. The empty container is 100 per cent void. The perfectly filled container is zero per cent voids.

Assuming perfection in our packing, as each piece of material is fit into place the per cent voids decrease proportionately and we have the straight line graph as shown in Fig. 1 (Line A).

Again, in theory this is easy, but in practice it is nôt possible. The following statement is without vigorous proof but it is offered as a statement of fact: "The greater the number of particles into which the single piece was broken, the harder it will be to piece them back together."

For any standard effort, less than perfection will be achieved. After some number of pieces are fitted into place the actual packing curve will depart from the theoretical. A larger container will be required to hold all of the pieces and there will be voids in the final structure (Fig. 1 – Line B).

The practical effect of this breaking up of single particles of an aggregate may be followed by another mathematical model based on this so-called "actual packing" phenomena.

Starting again with our single particle, crush it into several pieces. The result is an aggregate. The packed aggregate contains voids. We will follow the effect of continued breaking of the particles using another index, the apparent specific volume. This is the reciprocal of the apparent density and the units are cc per gram or cu ft per lb. This particular index was chosen because it gives a straight line plot under the conditions imposed by the model.

Efficiency Degree

It is necessary only to assume some set degree of efficiency in repacking particles derived from the breaking-up of the larger pieces. In this case, let us assume that in repacking the particles we are 70 per cent efficient. Our plot, Fig. 2, now starts with a single particle. There are no voids. The apparent density is the true density, and the apparent specific volume must also be the true value (for silica it is ($1/2.65 = 0.378$ cc/gm.). At 70 per cent solid

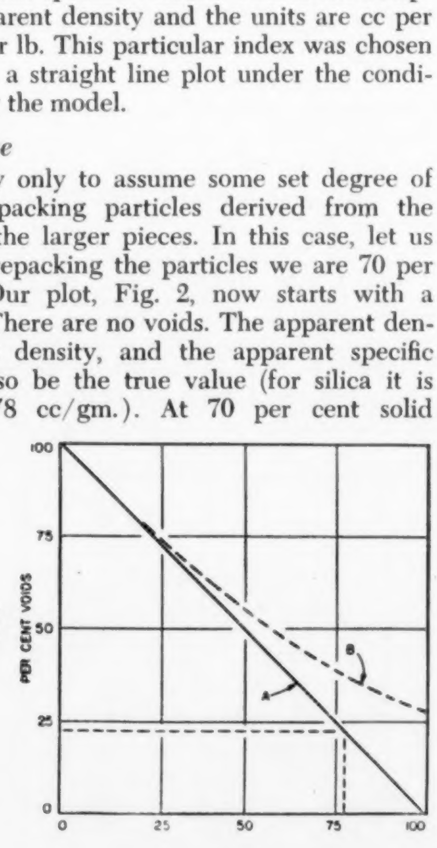

Fig. 1 – Percentage of material fitted in place.

*Michigan Standard Alloy Castings Co., Detroit.

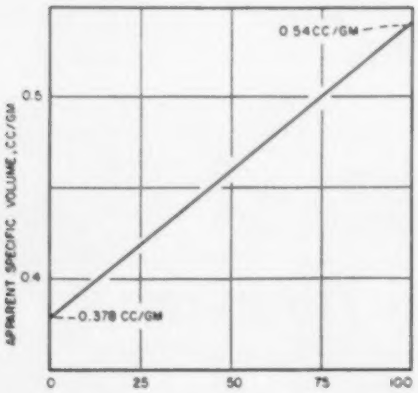

Fig. 2 – Left – Percentage of material finely crushed and repacked at 30 per cent voids.

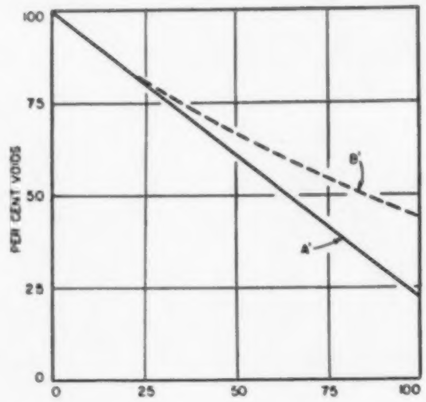

Fig. 3 – Right – Percentage of available material fitted in place.

the apparent density is (0.70 x 2.65) = 1.885 gm/cc the apparant specific volume = 1/1.855 = 0.54 cc/gm.

As we reduce fragments of the single grain to particles that we can repack to 70 per cent solid the plot of Fig. 2 is developed. The slope of the line depends on our efficiency in repacking: higher efficiencies given lesser slopes.

USE OF CRUSHED MATERIAL– SOME PIECES REJECTED

Start with the crushed material used in the previous discussion. Discard some pieces, say 20 per cent by weight. Proceed with the piecing together as previously discussed and the material supply is exhausted at 20 per cent voids as noted by the point on Fig. 1.

If, however, the remaining material is considered as being 100 per cent of that available, our progress record appears as in Fig. 3. According to our model, the more pieces missing the greater the final percentage of voids (Line A′). Because of lack of perfection in fitting what is available line B′ represents the more probable result.

USE OF NATURAL DEPOSITS OF SMALL PARTICLES– WITH OR WITHOUT FURTHER PREPARATION

The termination of line B′, Fig. 3, at 100 per cent of available material represents normal packing of foundry sands. We do not know what particles have been lost, but we can follow our progress in fitting in the missing particles if they were available. This is done in Fig. 4.

For the purpose of this illustration it is assumed that the sand packs to 60 per cent solid. According to the model used in Fig. 1 (Line A) 40 per cent of the material is missing when compared with a solid mass.

Figure 4 (Line 1) follows our progress in fitting the missing material back into place. The percentage added is calculated as the percentage of the mix present, e.g., if we started with 60 grams the 20 per cent figure refers to 15 grams added, etc.

15 divided by (15 + 60) = 20 per cent

40 divided by (40 + 60) = 40 per cent

Line 1 Fig. 4 again represents the perfect fit. It may be drawn as a straight line with no appreciable error within the limits encountered in usual practice. Line 2 Fig. 4 depicts the more probable results.

BLENDING OF NATURAL DEPOSITS, CRUSHED MATERIALS, OR FRACTIONS OF EITHER

Blending of natural deposits with each other or with machine crushed particles is the foundrymen's attempt to offset in part the effects of some previous loss of particles in handling, crushing, grading, or from some other cause.

The addition of coarse particles to a fine mixture is the reverse of Fig. 2 where coarse particles were crushed to make fine particles. The addition of silica flour to sand is an attempt to substitute fine particles for those lost, and to fill voids resulting from imperfect packing.

Thus, the mathematical models developed in Figs. 2 and 4 should serve as an indication of the probable results of blending and should also state the limits beyond which one cannot increase the density. The straight line represents perfection which we can approach but not attain.

Figure 5 is such a plot. The substitution of the "perfect fit" particles (after Fig. 2) are shown as solid lines. Experimental data points are connected by the broken line. The dry material was vibrated and tapped to "maximum" density. Each point represents an average of 5 to 10 experiments having a spread of not more than ± 0.6 per cent solid. The No. 60 Ottawa sand (washed and dried) packed to

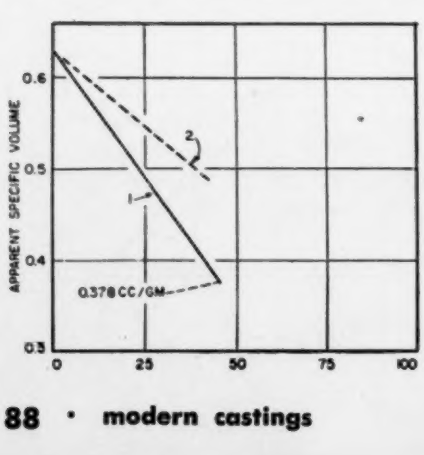

Fig. 4 – Percentage of missing material added.

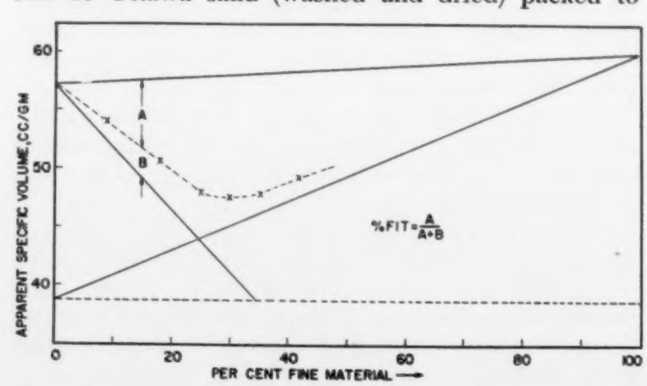

Fig. 5–Theoretical and actual packing for Ottawa No. 60 sand and silica flour (140).

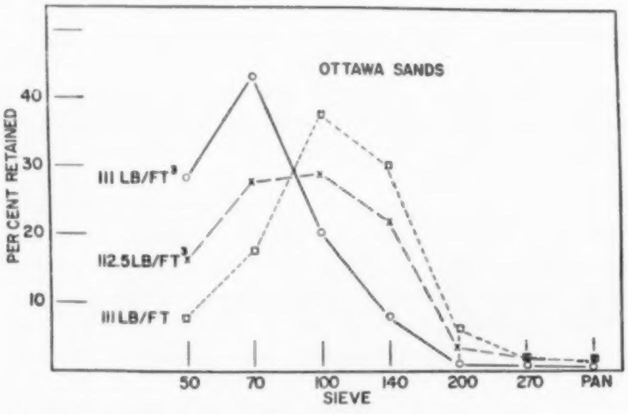

Fig. 6—Sieve distribution, Ottawa sands.

0.57 cc/gm and the minus 200 mesh silica flour to 0.60 cc/gm.

"Perfection", described as being a perfect fit of large and small particles, occurs at about 25 per cent silica flour; 0.433 cc/gm, 2.31 gm/cc, 87.4 per cent solid. Even with no interference between large and small particles we cannot achieve greater density. The actual maximum was reached at about 30 per cent silica flour; 0.476 cc/gm, 2.10 gm/cc, 79.5 per cent solid.

It is significant that even at the lowest percentage of silica flour used, 10 per cent, the original packing of the sand was changed to a significant degree. Further additions, served to increase the distance between sand grains to such an extent that more silica flour could be fit in than would have otherwise been possible. This caused the maximum density to occur at the higher than predicted percentage of silica flour.

MATHEMATICAL MODELS OF PARTICLE PACKING IN PRACTICES MENTIONED

This example was repeated for various distributions of sands. Using sands only (no flour), density increases greater than one per cent were rare. Data from the above cited experiment, along with data from other mixtures, are shown in Figs. 6, 7, and 8.

This emphasizes the need for a means to evaluate the "fit" of the various sizes of particles. Mathematical means for determining the sizes that will most probably fit, and the amounts of each size to use, are the subject of other papers. For those preferring a simple method, the described graphical approach allows rapid approximation of results to be expected from blending, with a minimum amount of data. In addition, it is possible to define the degree to which grains do "fit".

For example, Fig. 5 predicts a decrease in specific volume of 0.140 cc/gm at 25 per cent silica flour. The actual decrease was 0.097 cc/gm. The fit might well be described as 0.097/0.140 or 69 per cent. If the use of density is preferable the corresponding value is 63 per cent.

Because this definition of "fit" is based on actual results it must be present in one form or another in

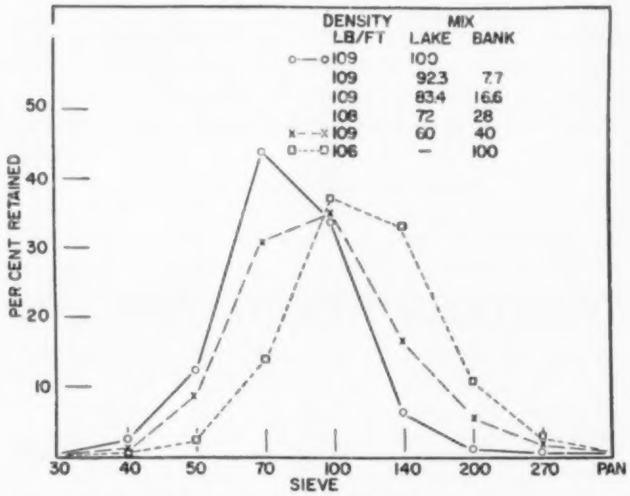

Fig. 7—Sieve distribution, lake and bank sands.

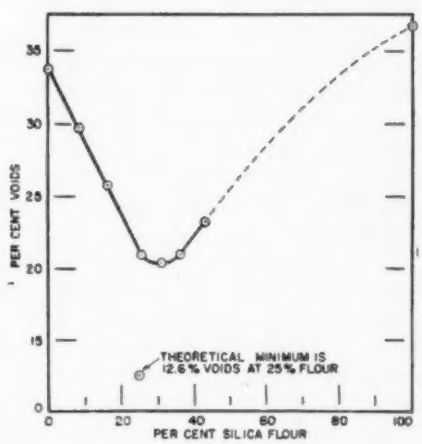

Fig. 8—Ottawa No. 60 base sand mixes dried at 120C, vibrated and tapped to maximum density.

any method of calculation if that calculation is to give usable results.

SUMMARY

Mathematical models, illustrated by graphs, are presented describing particle packing for cases of:

1. Imperfect packing resulting from inability to reposition particles exactly as in the original solid mass.
2. Loss or discarding of particles making it impossible to reconstruct the original solid mass.
3. Decrease in apparent density (increase in apparent specific volume) caused by decreasing particle size.

Using these models, a method is developed for describing: a) The "perfect" fit of two different groups of particles assuming no interference between the groups and, b) a proposed definition of "fit" as the ratio of actual packing density to the above described "perfect" fit.

The method allows a rapid approximation of the results to be attained from blending two groups of particles with a minimum of data.

PATTERN STANDARDS FOR PRACTICAL FOUNDRY USAGE

By

Ernest A. Geary*

Competition and the ability to make a profit are undoubtedly the two strongest motivators in the growth, strength, and leadership of our great free enterprise economy. Competition decides the products that will be built, the materials that will be used to produce them, and the method of forming this material into the final product. We in the pattern business depend for our existence upon competitively acquiring the tooling requirements of the sand casting industry.

The number of patterns required by the industry will be decided by how many items this industry can offer the cheapest method of product manufacture. Whether we are a pattern jobber or a captive shop, the number of items that we are successful in acquiring will be dependent not only on how efficiently we operate our shop, but upon what type of pattern the foundry will require to produce the specified casting.

We all know that for any given part, the type of pattern, material, technique used in its construction, and accuracy required can vary widely for many reasons.

PATTERN EQUIPMENT

One of the reasons for the many different types of pattern equipment which can be built today is the continued effort on the part of the sand casting industry to acquire more and more items in competition with other metal forming industries. The various techniques of making the sand mold by mechanical methods such as jolt-squeeze, sand slinger, blowing, diaphragm squeeze, and shell molding, have been utilized by the industry toward the reduction of their casting cost.

The elimination of more and more hand operations by the application of automatic devices and controls has improved the competitive position of castings, but it has had its effect upon the patternmaking business also.

The various techniques for making the sand molds definitely affect the pattern shop if they are to build suitable production patterns. A pattern built for a jolt-squeeze ramming method for any given design will have a different total mold production life than the same pattern if a sand slinger is used to make the mold. Similarly, the introduction of mechanization and automation both in the foundry and the machine shop affects the type of pattern that can be built to satisfy a given casting design.

The rigging of any pattern for a mechanized unit results in costs which are in addition to the actual casting shape. As hand operations are eliminated in the foundry, the pattern shop must provide the pattern with features that were not required in the heap-sand foundry. As mechanization increases in the foundry the pattern becomes more elaborate and more costly to produce any given casting.

MOLD MAKING IMPROVEMENTS

Thus the foundry that makes improvements in its mold-making procedures in order to make its castings cheaper will many times find itself restricted to higher activity items because of the increased pattern costs required to tool its mechanized units.

The obvious result of this situation is the criticism of the pattern shop by the foundry for its inability to obtain new work because the pattern costs are too high. Sometimes this is undoubtedly true, but it is also true that the foundry in its intense desire to have a low casting cost will attempt to make castings on mechanized units whose activity does not justify the pattern expenditure required to tool the unit.

For example, the expenditure of 20 dollars for an attached gate on a pattern which we will assume to reduce the casting cost five cents means that the foundry must make at least 400 castings before the effect of this expenditure can be justified to the ultimate casting customer. If the gains that are obtained in the foundry by mechanization are thus nullified by the increased pattern costs, the net result of progress will not be realized by the sand casting industry.

Pattern shops have realized this situation and indeed, great strides have been made in the use of new materials such as plastics, better use of existing materials, and improved methods used in the forming of these materials into the desired shape. Our continued efforts along these lines will benefit the competitive application of more mechanization in the foundry which will help the entire industry.

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*Westinghouse Electric Corp., Trafford Foundry, Trafford, Pa.

Any attempt on our part to better our pattern competitive position by lowering our quality standards can only perform a disservice to ourselves, the foundry and the industry. We must keep pace with the efforts of the foundry by supplying more elaborate patterns at reduced costs which satisfy the required production requirements of the part.

The request for pattern quotations received by the pattern shop may contain a wealth of information supplied by both the foundry and the ultimate casting user or it may consist of the simple statement, "Quote pattern to produce above part." With the many different types of patterns of various materials that can be made today, the buyer who is interested in acquiring several quotations can be assured of a wide spread between the high and low bidder by using the above-mentioned phrase.

Since in many cases the actual pattern is retained by the foundry and never seen by the actual pattern purchaser, the selection of the best value from an overall cost standpoint can seldom be known.

SAFETY MARGIN

Since in many cases a true evaluation could not be made even if the actual pattern was examined, it becomes a matter of record as far as the buyer is concerned that the pattern for a given part is in existence and the routine ordering of castings follows. Many casting users feel that once a pattern has been produced, castings can be ordered indefinitely without further expenditures on their part. This can result in the foundry supplying castings for years from a pattern which was built to produce the quantity on the original order with very little safety margin.

If the foundry finds this situation untenable, it may approach the customer for major repair money or for complete replacement of the pattern and readily obtain it. On the other hand the foundry may be criticized for maltreatment of patterns or may have to relinquish some of the profit margin in order to offer the customer a "cost reduction" to justify the replacement pattern expenditure.

Certainly this is not such an unusual chain of events that everyone of us cannot recall where difficulties with pattern equipment could be traced directly to lack of sound information when the pattern was originally quoted and constructed. When good information is supplied regarding the life of the design, normal ordering quantities, and normal yearly activity with the pattern quotation request, the casting user, foundry and pattern shop all benefit from the advances the industry has made in its methods.

PATTERN STANDARDIZATION

We all know that a pattern for producing one casting per year is entirely different than a pattern for producing 1,000 castings per day. While this is obvious, does not the same principle apply to cases where the difference between quantities is not so marked? I think we can all agree that the anticipated activity of a part is a large factor in deciding what type of pattern should be built and as such, becomes a contributing factor in any attempt to standardize patterns.

As an approach toward standardization of patterns by the amount of castings required, the author's company uses a system of pattern classification which directly relates pattern type with activity. With this system there are five classes of pattern equipment to designate to our customers the types of pattern equipment which can be built. Class One pattern equipment is designated as low cost equipment, usually made for one or two castings and the pattern is destroyed when notification is received that the castings produced from it have been accepted. When a customer specifies this type of activity, the pattern shop is only required to build the required shape as cheaply as possible, and the foundry gains the added advantage of not having to store the pattern or maintain it over an appreciable period of time.

A Class Two pattern is also usually a loose wood pattern. However, in this case the pattern is built with an anticipated life of 10 years. The activity for this classification is in the 5-10 castings per year category, which means the pattern must be built for a total production of from 50-100 castings. When a customer indicates that he wants a pattern for one large initial order with a possibility of small future activity, Class Three equipment is usually built.

A typical example of this category would be a machine-mounted wood pattern rigged for a specific molding unit and gated to foundry specifications. The activity figures for this classification of pattern may range from 100-250 pieces on the first order, with 50-60 castings per year afterwards for 10 years. This means that the pattern must be built for a total of from 600-850 castings.

Class Four pattern equipment is designated for low activity, long-life items for which a hardwood pattern mounted for machine molding, gated to foundry specifications, and reinforced with metal on the high wear areas is usually built. The activity of items in this category is usually 100-300 castings per year with a 10 year life. This means the pattern must be built to produce a total of from 1,000-3,000 castings.

Finally, Class Five pattern equipment is designated for high-activity long-life designs for which metal equipment is usually built. The activity figures of this type of pattern equipment are only limited by the production limitations of the foundry molding equipment.

Coupled with this program of classifying patterns by activity is the maintenance policy which is afforded our customers based upon this system. All repairs necessary to maintain the pattern capable of producing commercially acceptable castings, as specified by the part's engineering drawing, are assumed by the foundry for the Class Two, Three, and Four categories for the normal life expectancy of the pattern class.

Maintenance of Class Five equipment is assumed by the foundry on a permanent basis, which includes the replacement of the pattern when it can no longer be used for casting production. When the normal life expectancy of the Class Two, Three, and Four patterns has expired, and the pattern can no longer be economically repaired, replacement requests are entered against the casting customer.

It is felt that there are many advantages to be realized by this system of standard pattern classification as the author's company uses it. The buyer is made more aware of the importance placed on the life of the design and activity figures which he supplies on his requests for quotation. He more fully realizes the many types of pattern equipment that can be built for any given design, and what can be expected from various representative types.

PATTERN MAINTENANCE

The pattern maintenance policy offers the buyer an incentive to obtain accurate activity figures from his organization, since he cannot easily ignore or deny replacement pattern requests received because the foundry acted on erroneous information which he supplied. Finally, it gives the buyer a better tool to evaluate competitive pattern quotations because he knows the prices submitted are for a pattern capable of producing a specified number of castings.

With this system the pattern shop is given quite a bit of freedom in the selection of construction techniques and materials within the total production figures of the various classes. The ingenuity of the patternmaker is not restricted to the extent that he must use the same material for the pattern of a heavy-sectioned casting as he would for a relatively fragile casting.

The system promotes a better understanding in the pattern shop of the problems faced by foundry personnel on specific designs. The relative value of different construction methods, and new pattern materials, can be evaluated more effectively because of the foundry's responsibility under the pattern maintenance policy.

It is felt at the author's company that the foundry benefits from this system by receiving patterns built to run on its units and designed to produce the required number of castings during the life of the design. The foundry is made aware of the problems relating to patternmaking and how they can affect the foundry. It promotes a spirit of cooperation between pattern shop and foundry in the use of new materials and methods for patterns, which will enable the pattern shop to reduce its pattern costs.

Finally, it helps the foundry understand how requests for better pattern equipment than that needed to produce the specified number of castings can only hinder the foundry's acquisition of new work for their molding units.

This system of pattern standards has been adopted by the author's company as an approach to better understanding between casting user, foundry, and pattern shop. This has been accomplished with a minimum of restrictions to competitive bidding, which is a basic requirement of any standardization program if it is not to stifle the industry. It is felt that it has enabled the author's company to make better patterns, to produce more consistent castings, for a longer period of time. Can it do the same for you?

SHELL MOLDING SURVEY

A REPORT OF THE SHELL MOLD AND CORE COMMITTEE (8-N)*

INTRODUCTION

A little over a year ago, the Shell Mold and Core Committee (then known as the Shell Mold Material Testing Committee) was at a point in its program where it needed some assistance from the industry to plan its future program so as to best serve the industry. Toward this end, the Committee prepared a questionnaire which was distributed to a mailing list prepared by the members of the Committee. The questionnaire was designed to fulfill two purposes: 1) to compile a list of quality-control procedures used in shell-mold foundries to control the properties of incoming materials, as well as the shell-molding process; and 2) to compile a list of production difficulties encountered in shell molding with particular emphasis on reasons for scrap castings.

The questionnaire was mailed to 118 foundries. Twenty-seven reported data out of 36 respondents. Seven reported they did no shell molding. Two returned blank questionnaires. The data received have been tabulated and the pertinent results are covered in this report.

GENERAL FOUNDRY INFORMATION

Of the foundries reporting, 7 employed fewer than 100 people, 5 were in the 100-200 range, and 15 employed over 200 people. In reply to the question on the type of foundry operation, 8 reported captive, 16 jobbing, and 2 a combination of captive and jobbing. Sixteen foundries were in full shell-molding production, 7 in the pilot stage, and 4 in the development or experimental stage. The report on the types of metal poured showed that most foundries were pouring gray iron into shell molds. The breakdown by metals is given in Table 1.

SHELL-MOLD PRODUCTION DATA

To get an idea of the types of castings being made and the details related to the production of the castings, the foundries were asked to report the pertinent data for a typical casting. They were asked the end use of the casting, the number of castings per mold and weight per mold, pattern, mold, and core data, as well as the dimensional tolerances and the reason shell molding was used for this typical application.

As has been reported in other surveys on shell molding, the end use of the shell-molded castings covered a wide range of applications. Casting weights were reported from a minimum 0.02 lb to a maximum 151 lb. The majority of the applications reported were under 10 lb. The number of castings per mold varied from 1-80. The minimum casting section thickness reported was 1/16-in., while many reported 1/8-in. in all metals. Shell-mold thicknesses varied from 1/8-1/2-in. Sixty-three per cent of the foundries used shell cores, one-quarter of them using some type of wash on the cores.

Cast iron was the favored pattern material, preferred by 56 per cent of the foundries. Aluminum and steel were equally favored by 11 per cent of the foundries, while 15 per cent reported using combinations of metals for patterns. A silicone release agent was used by 85 per cent of the foundries, the balance using some type of wax for release.

The dimensional variation within a mold half was reported from a low of ±0.001 in. per in. to a high of ±0.025 in. per in. Most foundries reported a variation of ±0.005 in. per in. Variation across the parting line varied from ±0.003 in. per in.-±0.125 in. per in. with the majority reporting in the range ±0.005-0.015 in. per in. Variation around a shell core ranged from ±0.004 in. per in.-±0.020 in. per in.

Improved surface finish was the reason reported by 37 per cent of the foundries for turning to shell molding. Next in the order of importance were ability to cast to closer dimensions and the elimination or reduction of machining, each reported by 26 per cent of the respondents. Other reasons cited were cost reduction (15 per cent) and increased production (11 per cent).

SAND AND SAND-RESIN MIXTURES

All types of new sand were reported being used for shell molding. Two-thirds of the foundries purchased dried sands. Round, sub-angular, and angular

TABLE 1–BREAKDOWN OF METALS POURED

Metal	No. Foundries	%
Gray Iron	16	59
Malleable Iron	4	15
Steel	5	18.5
Stainless Steel	4	15
Magnesium	3	11
Aluminum	8	30
Brass and Bronze	3	11
Special Alloys	8	30

*8-N Committee Members: N. Sheptak, J. E. Bolt, G. I. Reynolds, R. J. Cowles, A. L. Graham, F. W. Less, R. J. Mulligan, R. A. Rabe, J. G. Smillie, W. H. Dunn, T. V. Linabury, R. E. Melcher, E. I. Valyi, J. M. Verdi.

grain sands were all used, with a preference being shown for sub-angular grain shape. The sands were described as 3 and 4 screen sands, with AFS GFN in the range of 81-110 most popular. Most of the foundries had some purchase specification on clay content of the sand.

Dry blends of sand and resin were reported used by 48 per cent of the foundries while 52 per cent reported using cold-coated mixtures and 19 per cent hot-coated mixtures. The use of additives to the sand-resin mixture was limited to a few foundries. The dump box method of investment was most widely used for shell molds while most shell cores were made by blowing.

QUALITY CONTROL

Sand. Sieve analysis was used by 59 per cent of the foundries for controlling the quality of incoming sand. Forty-one per cent analyzed for clay. Other control tests used were moisture content and loss on ignition.

Resin. No specific tests were used by the foundries for resin control.

Resin-Sand Mixture. Thirty per cent of the foundries used the 1/4-in. thick tensile strength specimen for controlling the mixtures. Several foundries reported using flexural strength, scratch hardness, and cure time as controls on the mixture. The 8-N tentative standard tensile test method was used by 15 per cent of the foundries.

Shell Mold Production. The color of cured shell molds was the most widely used production control. Eighty-five per cent of the foundries used some sort of color test. Next in order of preference were mold thickness tests (70 per cent) and mold weight tests (67 per cent).

One-half of the respondents indicated that new tests were necessary for coated resin-sand mixtures. Among the tests suggested were hot expansion, cracking tendency, hot tensile, cure, investment rate, hot and cold flowability, hot transverse, and flexural.

PRODUCTION PROBLEMS

Mold cracking and casting surface defects were listed as the most prevalent reasons for scrapped castings. In the order of decreasing frequency of mention, the problems reported were mold cracking, surface defects, stripping breaks, parting line bond failure, cold shuts, runouts, swells, burned-in sand, inclusions, and mold distortion.

FUTURE COMMITTEE WORK

As a result of the questionnaire survey, the Shell Mold and Core Committee 8-N has undertaken a study of the problem of mold cracking, which is a function of mold-wall movement or the thermal shock characteristics of a sand-resin mixture. Toward this end, the Committee is accumulating data on various hot-expansion tests as well as information on hot-tensile tests. It is hoped that out of this study will develop recommendations and tests for the elimination and control of mold cracking.

CONTENTS

Board Draws Record Number of Directors

AFS Directors with President L.H. Durdin presiding, held the Annual Board Meeting of the Society in Dearborn, Mich., Aug. 7-8. Twenty-one of the 24 Directors attended, the largest number to date.

This is the first time since 1950 that the meeting has been held outside of Chicago. The entire Board of Directors of the Detroit Chapter met with the AFS Board of Directors for dinner on the 7th.

Two new Directors were elected by the Board to terms expiring in April, 1959. The new Directors are:

▪ J.H. King, Archer-Daniels-Midland Co. (Canada), Ltd., Toronto, Ont., replacing the late Alex Pirrie.

W. D. McMillan, newly elected Director succeeding **G. P. Phillips.**

▪ W.D. McMillan, International Harvestor Co., Chicago, to complete the term of G.P. Phillips also of International Harvester Co., Chicago. Phillips was elected Director Ex Officio, the first named to this office as provided under the revised By-Laws.

Four Staff Officers were elected by the Board in an effort to relieve the President of a portion of his duties and to delegate greater responsibility to Staff members.

Staff Officers elected:

General Manager—Wm. W. Maloney.

Technical Director—S. C. Massari.

Secretary—A.B. Sinnett.

Treasurer—E.R. May.

Construction of the proposed Training & Research Institute Training Center building was postponed by the Board pending improved business conditions. The T&RI schedule of courses will continue to be held at foundry centers throughout the country.

A. B. Sinnett, former Assistant Secretary, elected as Secretary.

October Highlights

Regionals

15-16 . . **Michigan Regional Foundry Conference,** University of Michigan, Ann Arbor, Mich.

16-17 . . **All-Canadian Foundry Conference,** Royal Connaught Hotel, Hamilton, Ont.

17-18 . . **New England Regional Foundry Conference,** Massachusetts Institute of Technology, Cambridge, Mass.

30-31 . . **Purdue Metals Castings Conference,** Purdue University, Lafayette, Ind.

31-Nov. 1 . . **Northwest Regional Foundry Conference,** Multnomah Hotel, Portland, Ore.

Administration Meetings

14 . . **Region 4,** University of Michigan, Ann Arbor, Mich.

15 . . **Region 2,** Royal Connaught Hotel, Hamilton, Ont.

16 . . **Region 1,** Hotel Statler, Boston.

20 . . **Region 5,** Hotel Astor, Milwaukee.

AFS 1896

NEWS and VIEWS

National News

1958 T&RI Courses

Air Pollution Control & Legislation — **Oct. 1-3—Chicago**
Lecture course covering the laws and interpretation, problems, suggested solutions and the drafting of ordinances from the foundry standpoint. Registration fee $40.

Gating & Risering of Ferrous Castings — **Oct. 27-31—Chicago**
Lecture course on the problems relating to gating and risering. Intended for foremen, technicians, foundry engineers, supervisors, industrial engineers and production and quality control personnel. Fee $65.

Foundry Plant Layout — **Nov. 10-12—Chicago**
Lecture course on problems of rehabilitation or building of new plants. Intended for foremen, supervisors, industrial and production engineers and management. Registration fee $40.

Advanced Industrial Engineering* — **Dec. 8-12—Milwaukee**
Work sampling, rating practices, quality control including uses of motion pictures in these phases. Registration fee $125.

*Course originally scheduled for other dates.

REGISTRATION

AFS TRAINING & RESEARCH INSTITUTE COURSES

Application for enrollment in T&RI course.

☐ Air Pollution & Legislation ☐ Foundry Plant Layout
☐ Gating & Risering of Ferrous Castings ☐ Industrial Engineering

Name .... Position or Title ....

Important

Address ☐ Home ....

☐ Business ....

City ....Zone........State...............

Company ....

Make checks payable to: AFS Training & Research Institute

Mail to: AFS Training & Research Institute
Golf & Wolf Roads
Des Plaines, Ill.

Advance Sand Course Deals with Testing and Controls

■ Advanced techniques in sand testing, control and technology were presented to 37 foundrymen attending the T&RI-sponsored *Sand Control & Technology* course presented Aug. 11-15 at Rackham Memorial, Detroit.

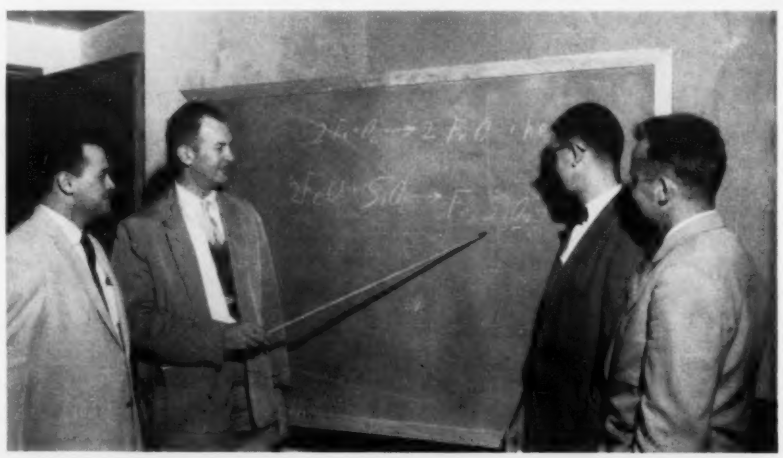
The course consisted of lectures and demonstrations given by eight outstanding foundrymen who donated their services.

Victor Rowell, Harry W. Dietert Co., Detroit, lead sessions on Testing & Tempering of Sand, Mold Wall Movement, Mold Wall Fracture, Mold Atmosphere and Metal Penetration into Mold Surface. Rowell and Ray Daskiewicz, also of Harry W. Dietert Co., conducted demonstrations.

Clyde A. Sanders, American Colloid Co., Skokie, Ill., discussed Casting Losses and Testing Clays & Special Sands.

Other speakers and their subjects: T. E. Barlow, Eastern Clay Products Dept., International Minerals & Chemical Corp., Chicago, *Mechanical Mold Properties;* Eugene Passman, Frederic B. Stevens, Inc., Detroit, *Casting Finish;* Anton Dorfmueller, Archer-Daniels-Midland Co., Cleveland, *Cores;* Robert McIlvaine, National Engineering Co., Chicago, *Sand Reclamation;* and Charles Locke, Crucible Steel Castings Co., Cleveland, *Heat Transfer Through Mold Wall.*

T&RI Sand Control and Technology course presented during August drew foundrymen from the United States and Canada. Lectures and demonstrations were held at Rackham Memorial Foundation, Detroit. The advanced course was for foundrymen having some experience in sand testing, control and technology. Included were statistical controls, mold wall movement, hot deformation, creep deformation, mold atmosphere, heat transfer, mechanical sand properties, metal penetration and quality control.



Instructor **Victor Rowell,** Harry W. Dietert Co., Detroit, reviews course material with **John Bicher** and **Joseph Kuterbach,** Stanley G. Flagg & Co., Stowe, Pa.; and **Edward J. Richard,** Bethlehem Steel Co., Bethlehem, Pa.

AFS Joins in Program to Aid Vocational Teachers in Presenting Foundry in Secondary Schools.

■ An intensive study of foundry techniques was presented to 30 Illinois vocational instructors at the University of Illinois Aug. 18-22. The program was developed to promote a workshop in cast metals for the trade and industrial vocation machine shop instructors.

It was sponsored by the Illinois State Board of Vocational Education, the University of Illinois and the American Foundrymen's Society.

The attending instructors, all of whom have education degrees and are journeyman machinists, are currently teaching in Illinois high schools and vocational programs.

Workshops were used to present individual instruction with four of the five days devoted to the university's foundry laboratory where the instructors practically applied methods of coremaking, molding and melting, patterns and castings.

Instructors were divided into three groups and on Monday, Tuesday and Thursday attended 3-hour sessions in both morning and afternoon alternating between lecture periods and work.

Wednesday morning was devoted to a panel discussion on educational policy and the teaching of related information. In the afternoon labor and management representatives told how vocational machine shop programs can be geared to new technological changes.

Friday morning all groups attended sessions on cupola principles and operation. The program was concluded with discussions and evaluations in the afternoon.

Instructors for the Illinois workshops were Prof. James Leach and Norman Donze of the University's mechanical engineering department and A.B. Sinnett, AFS Secretary.

AFS General Manager Wm. W. Maloney was the main speaker at the Thursday evening banquet which was attended by 15 area foundrymen in addition to the vocational instructors.

AFS participation in the workshop proved highly successful to the Society as well as vocational instructors and other sponsors of the program. AFS furnished kits of material including text books, outlines of sample courses and considerable related material.

Assistance by the Society in developing better cast metal instruction in the secondary school systems is available to interested state educational groups.

At the speakers table of the Illinois workshop are (left to right) **Millard Berry,** Champaign, Ill., high school, president, Illinois Vocational Machine Shop Instructors; **Bert Bevis,** Caterpillar Tractor Co., Peoria, Ill., and AFS Education Division Chairman; **E. M. Claude,** chief, trade and industrial education, Illinois State Board of Vocational Education, Springfield, Ill.; **Wm. W. Maloney,** AFS General Manager; **Robert Newall,** supervisor, trade and industrial education, Illinois State Board of Vocational Education, Springfield, Ill.; **Frank W. Shipley,** Caterpillar Tractor Co., Peoria, Ill., and former AFS President; Prof. **James Leach,** mechanical engineering department, University of Illinois and member of AFS Education Division; **Charles E. Drury,** Central Foundry Div., GMC, Danville, Ill. and AFS Regional Vice-President.

Prof. **James Leach** (in cap) supervises Illinois high school teachers as they pour a casting during a 5-day workshop on foundry practices held at the University of Illinois.

Schroeder Completes Puerto Rican Project

■ Establishing a foundry section of manufacturing processes and acting as a consultant to the College of Agricultural and Mechanical Arts, University of Puerto Rico, made a busy summer for Prof. Roy W. Schroeder, Professor of Mechanical Engineering, University of Illinois, Navy Pier, Chicago.

Prof. Schroeder is Vice-Chairman of the AFS Education Division.

In a letter to AFS Headquarters, Prof. Schroeder made the following comments about his Caribbean tour of duty:—

"Things are beginning to shape up—materials, machines and supplies are being received . . . expect to start instruction about August 15 . . . I have visited several plants—one dates back to the days when everything was done by hand. Another is a small shop with a jolt stripper-roller conveyor, shakeout and sand conditioning unit . . . A completely modern die casting plant is turning out some fine products . . . A nearby chinaware factory has a good supply of fine white silica sand suitable for molding."

major AFS meetings

OCTOBER

1-3 . . . **T&RI Air Pollution Control & Legislation course,** Hamilton Hotel, Chicago.

14 . . . **Region 4 Administration Meeting,** University of Michigan, Ann Arbor, Mich.

15 . . . **Region 2 Administration Meeting,** Royal Connaught Hotel, Hamilton, Ont.

15-16 . . . **Michigan Regional Foundry Conference,** University of Michigan, Ann Arbor, Mich. Sponsors: Central Michigan, Western Michigan, Detroit, Saginaw Valley Chapters; Michigan State University and University of Michigan.

16 . . . **Region 1 Administration Meeting,** Hotel Statler, Boston.

16-17 . . . **All-Canadian Regional Foundry Conference,** Royal Connaught Hotel, Hamilton, Ont. Sponsors: Ontario and Eastern Canada Chapters.

17-18 . . . **New England Regional Foundry Conference,** Massachusetts Institute of Technology, Cambridge, Mass., Sponsors: New England and Connecticut Chapters.

20 . . . **Region 5 Administration Meeting,** Astor Hotel, Milwaukee.

27-31 . . . **T&RI Gating & Risering of Ferrous Castings course,** Hamilton Hotel, Chicago.

30-31 . . . **Purdue Metals Casting Conference,** Purdue University, Lafayette, Ind. Sponsors: Central Indiana, Michiana Chapters; Purdue University.

31-Nov. 1 . . . **Northwest Regional Foundry Conference,** Multnomah Hotel, Portland, Ore. Sponsors: Washington, Oregon, British Columbia Chapters; Oregon State College Student Chapter.

NOVEMBER

7 . . . **Region 6 Administration Meeting,** Peabody Hotel, Memphis, Tenn.

10-12 . . . **T&RI Foundry Plant Layout course,** Hamilton Hotel, Chicago.

DECEMBER

8-12 . . . **T&RI Advanced Industrial Engineering course,** Marquette University Management Center, Milwaukee.

8 . . . **AFS Nominating Committee, Annual Meeting,** Sherman Hotel, Chicago.

9 . . . **AFS Board of Awards, Annual Meeting,** Union League Club, Chicago.

10 . . . **T&RI Trustees, Mid-Year Meeting,** Union League Club, Chicago.

JANUARY

16 . . . **Region 3 Administration Meeting,** Hotel Statler, Cleveland.

FEBRUARY

11 . . . **AFS Board of Directors, Spring Meeting,** Palmer House, Chicago.

12-13 . . . **Wisconsin Regional Foundry Conference,** Schroder Hotel, Milwaukee. Sponsors: Wisconsin Chapter; University of Wisconsin Student Chapter.

26-27 . . . **Southeastern Regional Foundry Conference,** Hotel Tutwiler, Birmingham, Ala. Sponsors: Birmingham, Tennessee Chapters; University of Alabama Student Chapter.

MARCH

12 . . . **Region 7 Administration Meeting,** Huntington Hotel, Pasadena, Calif.

APRIL

13-17 . . . **AFS Castings Congress & Engineered Castings Show,** Hotel Sherman and Morrison, Chicago.

Follow Suggestions to Make Exhibit Dollar Go Farther

■ How castings can be more profitably used as finished products or as vital components will be dramatized for castings buyers and designers at the 2d Engineering Castings Show. The Show, to be held at the Hotel Sherman, Chicago, April 13-17, will emphasize the flexibility, quality and economy of castings.

W.N. Davis, AFS Exhibit Manager, states that early indications point to a sell out of the 25,000 sq ft of exhibit space. To increase the effectiveness of exhibitor's booths, Davis has several suggestions:

Planning Booth

- Stress the range of products, technical data, design illustrations and actual applications.
- Keep all displays related to the booth.
- In planning the booth lay it out to scale, make it easy for visitors to enter. Avoid excessive decoration or other distractions. Allow space where blueprints can be spread out and examined.
- If possible have end products shown which incorporate your castings.

Operating the Booth

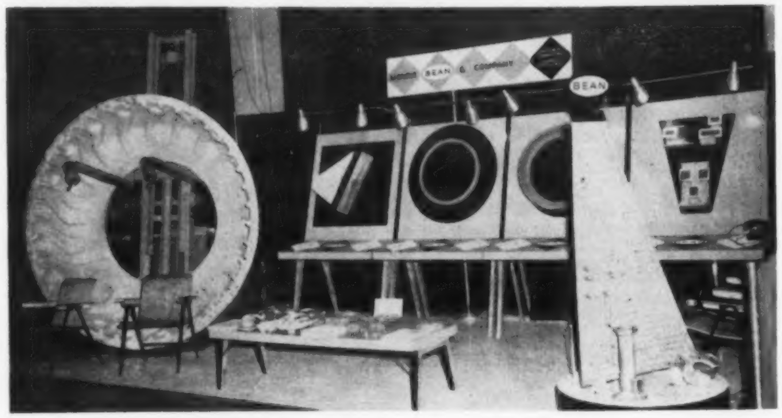
Have on hand the best literature available on your products. In addition to your own catalogs, literature published by AFS and trade associations will complement your display.

- Send engineers or men who are qualified to discuss design-production problems intelligently.
- See that all castings exhibited are well identified as to tolerances, chemical properties, applications, weight saving and machining time.
- Plan a daily sales conference throughout the show to go over prospects, questions and jobs under consideration.

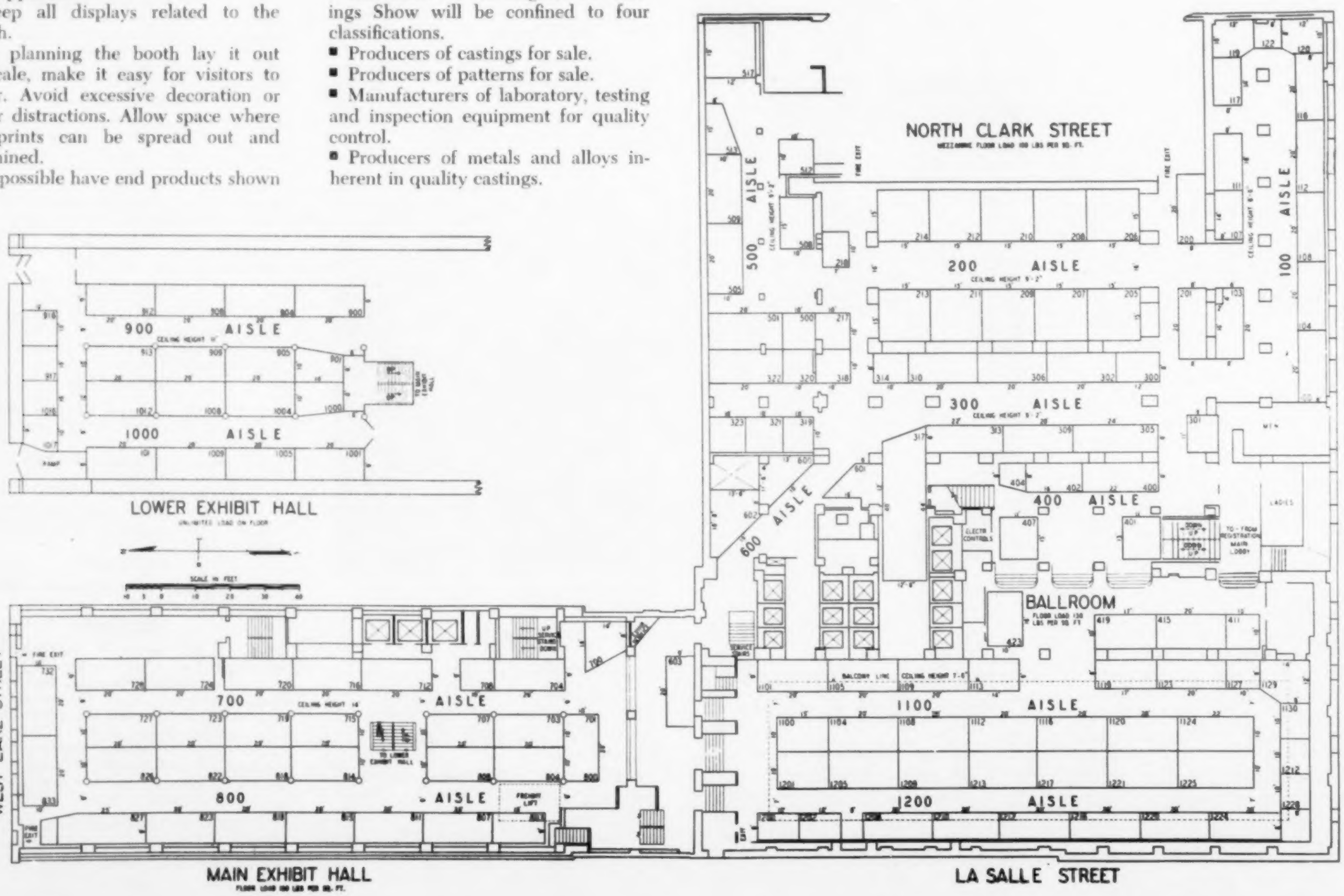
Exhibitors at the Engineered Castings Show will be confined to four classifications.

- Producers of castings for sale.
- Producers of patterns for sale.
- Manufacturers of laboratory, testing and inspection equipment for quality control.
- Producers of metals and alloys inherent in quality castings.

Ride the Upswing in '59!



In designing booths exhibitors are reminded that customers want to see actual products and discuss specific problems. Booths should be planned so that applications can be shown. Keep in mind that castings, patterns or products are being sold, not displays. Keep all displays related to the product.



Floor Plan of Engineered Casting Show to be Held April 13–17 in Chicago

Division Changes

Sand Division

■ Seven new committee chairmen and three new coordinators were appointed by the Sand Division Executive Committee at its June meeting held in Chicago.

The new chairmen:

Core Test Committee—D. R. Chester, Archer-Daniels Midland Co., Cleveland.

Mold Surface Committee—G. J. Vingas, Wehr Steel Co., Milwaukee.

Shell Mold & Core Committee—R. A. Rabe, General Motors Corp., Detroit.

Materials Used in Malleable Foundries Committee—D. S. Dalton, Racine, Wis.

Effects of Carbonaceous Materials Committee—P. W. Green, General Electric Co., Erie, Pa.

Sand Test Handbook Revision Committee—F. P. Goettman, Standard Sand Co., Grand Haven, Mich.

Basic Concepts Committee—J. B. Caine, Consultant, Cincinnati.

The three new cordinators are T. E. Barlow, Eastern Clay Dept., International Minerals & Chemicals Corp., Chicago; C. E. McQuiston, Advance Foundry Co., Dayton, Ohio; and Nicholas Sheptak, Dow Chemical Co., Midland, Mich.

Pattern Division

New division officers have been elected.

Chairman—O. C. Bueg, Arrow Pattern & Engineering Co., Erie, Pa.

Vice-Chairman—J. M. Kreiner, National Malleable & Steel Castings Co., Cleveland.

Secretary—R. L. Olson, Dike-O-Seal, Inc., Chicago.

Refractories Manual

J. P. Holt, Basic, Inc., Cleveland, has replaced R. H. Stone as committee chairman.

SH&AP to Publish New Industry Developments

■ Increased emphasis on providing foundrymen with the latest developments in safety, hygiene and air pollution has been approved by the SH&AP Control Steering Committee.

Recommended plans include:

▪ Bringing existing codes up to date and published as a supplement to the AIR POLLUTION MANUAL.

▪ Publication in MODERN CASTINGS or mailings of the latest developments in air pollution.

▪ Publication of various phases of insurance written by or obtained from insurance representatives serving on SH&AP committees.

Membership Pins Available

■ Three types of membership pins may now be purchased for $1 through the Membership Department, AFS Central Office, Golf & Wolf Roads, Des Plaines, Ill.

Both the screw type and the pin-back type are available for lapel use and a tie-tack is also available for wearing on the tie. Twenty-five and 50 year membership pins are available on request.

Members of the **Light Metals Division** and **Die Casting & Permanent Mold Division** jointly sponsored a luncheon at the 62d Convention. F. C. Bennett, and C. E. Nelson, Dow Chemical Co., Midland, Mich., presided. Others in pictures on panel which discussed **Automatic Ladling of Light Metals** are: R. C. Haverberg, AC Spark Plug Div., GMC, Flint, Mich.; C. H. George, Western Electric Co., Baltimore, Md.; and H. Eriksen, Chysler Corp., Kokomo, Ind.

Brass & Bronze Picks Theme for Convention

■ "Methods for Quality Control of Brass and Bronze Castings" has been selected as the theme of the Brass & Bronze Division for the 1959 Convention.

Technical talks aimed at this general subject will be supplemented by a round-table luncheon and a shop course. The round-table discussion will be designed to emphasize advantages of brass and bronze castings.

Topics to be covered will be physical and mechanical properties, corrosion and applications.

According to R. J. Keeley, Division Chairman, "The shop course program will deal with casting quality and specifically with the metallurgical and foundry aspects of quality control."

Among the technical papers considered for the 1959 Convention are:

▪ A research committee report on work conducted at the University of Michigan.

▪ A paper on electrical conductivity in copper-base alloys.

▪ A paper reporting original work done in England.

Tentative Schedule of Technical Sessions
AFS Castings Congress & Engineered Castings Show
April 13-17, 1959 . . . Hotels Sherman & Morrison

TIME	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
8:00 am	Authors Breakfast	Authors Breakfast	Authors Breakfast	Authors Breakfast	Authors Breakfast
9:30 am to 11:30 am	Light Metals Malleable Pattern	Brass & Bronze Pattern Malleable SH&AP T&RI Trustees	Annual Business Meeting & Hoyt Lecture	Steel Ductile Iron Fundamental Papers	Sand Heat Transfer Ductile Iron
12:00 noon	Light Metals Luncheon Malleable Luncheon	Brass & Bronze Luncheon Pattern Luncheon Board of Directors Luncheon & Meeting	Management Luncheon	Steel Luncheon Gray Iron Luncheon Past Presidents Luncheon	Ductile Iron Luncheon
2:00 pm to 4:00 pm	Brass & Bronze Sand Pattern	Light Metals Education Industrial Engineering & Cost	Steel Sand Die Casting & Permanent Mold Gray Iron	Sand Heat Transfer Ductile Iron Fundamental Papers	Gray Iron Plant & Plant Equipment
4:00 pm to 5:30 pm	Brass & Bronze Malleable Shop Course	Sand Light Metals Malleable Shop Course Gray Iron Shop Course	Industrial Engineering & Cost Die Casting & Permanent Mold Gray Iron Shop Course	Steel Gray Iron	
6:00 pm		Canadian Dinner Sand Dinner	Annual Banquet	Alumni Dinner	
8:00 pm to 10:00 pm	Sand Shop Course				

Utilizing New Developments—Theme of Michigan Conference

■ Critical examination of new developments in the metalcasting industry including design, material, melting, molding and marketing and the ways by which they can be put to profitable use will be discussed at the Michigan Regional Foundry Conference.

The conference, to be held Oct. 15-16 at the University of Michigan, Ann Arbor, Mich., is sponsored by the AFS Central Michigan, Western Michigan, Detroit and Saginaw Valley Chapters and the University of Michigan and Michigan State University.

W. C. Truckenmiller

W.C. Truckenmiller, Albion, Mich., is Conference Chairman. David I. Jacobson, Grand Haven Brass Co., Grand Haven, Mich., is Program Chairman.

WEDNESDAY, OCT. 15

(Morning Session)

Cast to size session—The principal new molding techniques for obtaining accurate dimensions will be discussed by experts in each field. In addition to presenting the new developments in each process, three representative castings will be analyzed by each speaker.

Shell Molding – Joseph Orloff, Saginaw Malleable Iron Div., GMC, Saginaw, Mich.

Investment Casting & Related Processes – Charles W. Schwartz, Misco Precision Casting Co., Whitehall, Mich.

CO_2 Process – Frank Ilenda, Diamond Alkali Research Center, Painesville, Ohio.

Parlanti Permanent Mold Process –C. A. Parlanti, Niforge Engineered Castings, Inc., Boston.

Die Casting – J. L. Pedicini – Congress Die Casting Div., Tamm Corp., Detroit.

Sand Molding, Graphite Molding & Other Processes – Dr. R. A. Flinn, University of Michigan, Ann Arbor, Mich.

Luncheon will feature "The Buhrer Automated Molding and Pouring Method" with comments by A. H. Homberger, American Automation Corp., Ann Arbor, Mich.

(Afternoon Session)

Melting sessions. Examination of new developments in melting techniques and materials will be featured.

Ferrous – "New Developments in Cupola Practice," W. Levi, Lynchburg Foundry Co., Radford, Va.

Non-Ferrous – "Induction Furnace Melting of Brass & Bronze Alloys," speaker to be announced.

Non-Ferrous – "Induction Melting of Aluminum and Zinc Alloys for Sand, Permanent Mold and Die Casting Industries," speaker to be announced.

Steel – New Developments in Steel Melting, Paul Gouwens, Armour Research Foundation, Chicago.

Gray Iron – "New Developments in Gray Iron Melting," H. H. Wilder, Vanadium Corp. of America, Chicago.

Evening banquet to be held at the Washtenaw Country Club.

THURSDAY, OCT. 16

(Morning Session)

Sand – "Synthetic Sands for Ferrous and Non-Ferrous Foundries," C. A. Sanders, American Colloid Co., Skokie, Ill.; W. Shartow, Chevrolet Grey Iron Foundry Div., GMC, Saginaw, Mich.

Design – "Stress Analysis & Design," Robert Frank, Superior Steel & Malleable Iron Co., Benton Harbor, Mich.

Material – "Castings & the Automobile Industry," Conrad Orloff, General Motors Technical Center, Warren, Mich.

The luncheon session will feature a talk on "New Developments in Practical Application of Atomic Energy" by Roger Leathermann, University of Michigan, Ann Arbor, Mich.

Tour of reactor at University of Michigan and the new automotive-engineering laboratories.

Southeastern Chairmen

■ M. D. Neptune and J. R. Cardwell, Chairman and Vice-Chairman of the Birmingham District Chapter have been named General Chairman and Program Chairman of the 1959 Southeastern Regional Foundry Conference to be held Feb. 26-27 at the Hotel Tutwiler, Birmingham, Ala.

Limitations on enrollment at T&RI courses permit individualized instruction. **M. K. Young** shows the latest techniques to **Albert Bolmer,** Taylor-Wharton Co., Div. Harsco Corp., High Bridge, N.J.; **W. A. Macnider, Jr.,** Chicago-Dubuque Foundry Co., Chicago; **Oren Layton,** Argonne National Laboratory, Lemont, Ill.; and **R. J. Porter,** General Dynamics Corp., Electric Boat Div., Groton, Conn.

T&RI Patternmaking Course Emphasizes New Techniques

■ New materials, processes, techniques and their applications were emphasized at the T&RI *Patternmaking* course presented Aug. 18-20 in Chicago.

Among the newer processes discussed were plastic foundry patterns and shell mold and shell core equipment. Advantages and applications of plastic patterns were outlined and a demonstration made illustrating casting resins and laminating.

Shell mold and shell core pattern equipment discussions included design considerations, pattern materials, how to make the pattern stripping pins and core boxes.

Patternmaking materials covered included wood patterns and plaster and gypsum cements. Sessions were also held on production pattern equipment and core box design.

Six foundrymen served as instructors. Those contributing their time and the subjects were:

John F. Roth, Cleveland Standard Pattern Co., Cleveland, *Wood Patterns;* William Cheek, General Motors Corp., Danville, Ill. and J. N. Mathias, Accurate Match Plate Co., Chicago, *Production Pattern Equipment;* M. K. Young, U. S. Gypsum Co., Chicago, *Plaster Patterns & Gypsum Cements* and *Plastic Foundry Patterns;* Z. Madacey, Beardsley & Piper Div., Pettibone Mulliken Corp., Chicago, *Core Blowing;* Richard L. Olson, Dike-O-Seal, Inc., Chicago, *Core Box Design;* and Fred Landmann, Brillion Iron Works, Brillion, Wis., *Shell Mold & Shell Core Pattern Equipment.*

Classes were conducted for two days at the Hamilton Hotel with the third day spent at the U. S. Gypsum Co. laboratories.

Instructor **M. K. Young,** U.S. Gypsum Co., Chicago, conducts demonstration for T&RI Patternmaking class. Both lectures and demonstrations were conducted during the 3-day course.

Name National AFS Nominating Committee

■ A nominating committee to select Officers and Directors at the AFS 1959 Annual Business Meeting was named in August by the Society's Board of Directors.

Six committee members were named from lists submitted by chapters eligible this year to suggest members.

These six together with the two immediate past presidents form the nominating committee which will meet Dec. 8 in Chicago to nominate a President, Vice-President, and six Directors, endeavoring, as prescribed by the AFS By-Laws, "to provide equitable and constant regional representation, and . . . representation for the several branches of the castings industry."

Members of the Nominating Committee are:

Past President **Frank W. Shipley**, Caterpillar Tractor Co., Peoria, Ill.

Past President **Harry W. Dietert**, H. W. Dietert Co., Detroit, Mich.

F. A. Dun, Babcock & Wilcox Co., Barberton, Ohio, representing Region 3–Chapter Group G–Canton District –Gray Iron and Steel.

E. W. Deutschlander, Worthington Corp., Buffalo, N. Y., representing Region 1–Chapter Group E–Western New York Chapter–Gray Iron.

D. G. Schmidt, H. Kramer & Co., Chicago, representing Region 5–Chapter Group K–Chicago Chapter –Supplies.

J. D. Tracy, Salmon Bay Foundry Co., Seattle, representing Region 7–Chapter Group R–Washington Chapter–Gray Iron.

Marcel Trottier, Quebec Iron & Titanium Corp., Sorel, Que., representing Region 2–Chapter Group D–Eastern Canada–Supplies.

L. J. Woehlke, Spring City Div., Grede Foundries, Inc., Waukesha, Wis., representing Region 5–Chapter Group L–Wisconsin Chapter–Gray Iron and Steel.

Northwest Regional Stresses Latest in Foundry Techniques

■ "Let's Build Today's Foundry," is the theme of the 9th Annual Northwest Regional Conference to be held Oct. 31-Nov. 1 at the Multnomah Hotel, Portland, Ore.

Plant layout, materials handling and work simplification will be stressed on the opening day. Molding methods, modern coremaking practices and new core processes will constitute the program for the second day.

The conference is sponsored by the AFS British Columbia, Oregon and Washington Chapters with the Oregon State College Student Chapter. The Oregon and Oregon State College Student Chapters will be hosts.

F.M. Menzel, Rich Mfg. Co., Portland, Ore., is General Chairman and A. A. Belusko, Electric Steel Foundry Co., Portland, Ore., is Program Chairman.

The tentative program:

FRIDAY, OCT. 31

9:30 am – *Potential Growth of Northwest Foundries,* a talk.
10:00 am – *Important Trends in European Foundry Practice,* film.
10:45 am – *Plant Layout Session,* discussion on foundry mechanization and modernization.
12:30 pm – *Luncheon,* welcoming address by Portland Mayor Terry Shrunk.

F. M. Menzel

2:00 pm – *Materials Handling Panel* dealing with lift trucks, conveyors and materials handling in cleaning room.
4:00 pm – *Work Simplification Session.*
7:00 pm – *Banquet.*

SATURDAY, NOV. 1

9:00 am – *Comparison of Present Molding Methods*–panel discussion of shell, permanent, ceramic and CO_2 molding, mold blowing and sand slinging.
12:00 Noon – *Luncheon.*
2:00 pm – *Modern Coremaking Methods,* film.
2:30 pm – *New Core Processes,* panel session covering shell, CO_2 and cold-set cores.
7:00 pm – *Dinner and Dance.*

Competition Opens for Trainees in Five Divisions of AFS Apprentice Contest

■ Competition starts Oct. 1 in the five divisions of the 1959 AFS Robert E. Kennedy Memorial Apprentice Contest. Closing date is March 16, 1959.

Any apprentice, learner or trainee in the metalcasting industry who has not had more than five years experience in patternmaking or four years molding experience is eligible. Competition is held in wood patternmaking, metal patternmaking, steel molding, gray iron molding and non-ferrous molding.

Cash Prizes

Apprentices will compete for cash prizes and certificates of recognition. First place winners in each division of national competition will receive \$100; 2d place, \$75; 3d place, \$50. In addition 1st and 2d place division winners will have their round-trip travel expenses paid to the 1959 AFS Convention in Chicago and receive their awards personally. Certificates of recognition will be presented to all winners in each division.

Judging

Judging is conducted on a point-score basis determined by the Apprentice Contest Committee. Following is the point scoring system for the 1959 contest:

Wood Patternmaking	
Accuracy according to drawing	35 max.
Moldability	35 max.
Workmanship	20 max.
Time	10 max.
Total	100 max.
Metal Patternmaking	
Accuracy according to drawing	50 max.
Workmanship	30 max.
Time	20 max.
Total	100 max.
Molding Divisions	
Gates & Risers	20 max.
Yield	10 max.
Cleanability	10 max.
General appearance	20 max.
Soundness	25 max.
Time	15 max.
Total	100 max.

Chapter Contests

All Chapters are encouraged to sponsor local elimination contests. The 1959 Rules and Regulations approved by the Apprentice Contest Committee must apply for all local contests. Chapters must furnish immediately, to the Education Division, AFS Central Office, the name of one person as the official contact for all correspondence concerning the contest and to receive all contest materials and instructions.

At the time patterns and/or blueprints are requested for local contests, the AFS Central Office must be furnished with the full names, companies and respective divisions of entry for all intended contestants. The official numbered identification tags for use by all contenders can not be provided until such information is received since all entry numbers are identified only at the Central Office.

It is suggested that local Chapters appoint a committee to make arrangements where necessary for foundry and pattern equipment and supplies required for contestants. Patterns, blueprints, identification tags, shipping and other special instructions may be obtained from the Central Office.

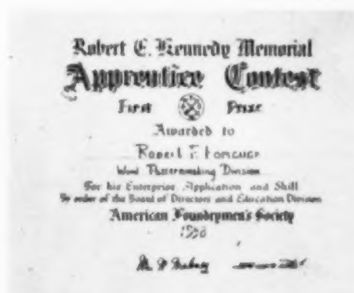
Each Chapter is eligible to submit the first three local winners in each of the five divisions for competition in the national contests.

Plant Contests

The same provisions apply with the following exceptions:

- All entries from plants located in the area where a local contest is held must clear through such Chapter contest to be eligible for the national contest.

- Where an individual plant conducts its own contest without Chapter affiliation, only the first place winner in each of the five divisions is eligible for national competition.



Certificates awarded to apprentice contest winners.

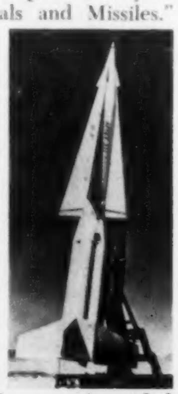
Winning entries from local chapter contests or individual plant contests are to be shipped to Prof. R. W. Schroeder, University of Illinois, Navy Pier, Chicago, not to the AFS National Office.

Chapter News

Gen. Colby Tells NEO About Metals, Missiles

■ "An outstanding example of the contribution of the foundry industry to the Army's space program can be found in the Jupiter C multistage rocket—the vehicle which launched all our Explorer earth satellites . . . Magnesium castings provide the support for the three upper stages of the missile and form the hub of the spin launcher itself. They are two or three times as strong and rigid as previously used weldments. Despite vigorous testing, we have yet to break one!", he said at the September meeting.

These words of praise came from a man in a position to know—Brigadier General Joseph Colby, Deputy Commander of the U. S. Army Ordnance Missile Command. The General carried 175 members and guests of the AFS Northeastern Ohio Chapter to the brink of outer space in a dynamic talk on "Metals and Missiles." A special luncheon and press conference was set up for members of the Cleveland newspapers, radios and TV stations, representatives of business and industrial magazines, and the Chapter board of directors. General Colby was the honored guest and spoke freely and occasionally "off the record" about the nation's guided missile program, satellite plans, national defense and Russian competition in these fields.



According to the General, "The Army's missile capabilities will be enhanced as the newest member of the Nike family of surface-to-air weapons, the Nike Hercules, is sited around key U. S. cities." The Hercules already has a reliability index of 85 per cent and has successfully engaged targets at altitudes in excess of 100,000 ft and at ranges greater than 100,000 yards.

To meet the threat of guided missile attack the Army Rocket and Guided Missile Agency has now under development the Nike Zeus, an anti-missile missile.

A run down on some of the castings currently serving on missiles included: 1) flanges for propellant plumbing (aluminum alloy 356); 2) fittings (aluminum alloys 220-TY, almag 35, 356, A-356 and various magnesium alloys); 3) structural brackets (aluminum and magnesium alloys); 4) spacers (aluminum and magnesium alloys); and 5) valve bodies (stainless steel, aluminum alloys and bronze).

And what does the Army want in its future castings? Basically, three things: 1) improved mechanical properties, especially at minus 180 C; 2) improved casting with cheaper patterns, shorter lead time and cheaper tooling; 3) general product improvement, such as better weldability and greater reliability so thinner cross sections can be depended on.

After showing a color movie of all the Army missiles in action and answering innumerable questions that were mostly "out of this world."—*J. H. Schaum.*

A unique casting weight guessing contest was held by the **Wisconsin Chapter** at its annual picnic. All castings were bolted to the table to prevent lifting and all were painted to prevent identification of metal.

Canton Chapter Holds Summer Picnic

The 15th annual chapter picnic was held at Barberton Brookside Country Club. The picnic committee was headed by Chairman **Ray Bossong,** American Steel Foundries, Alliance, Ohio and Co-Chairman **F. A. Dun,** Babcock & Wilcox Co., Barberton, Ohio.

Prizes for the picnic were handled by **Robert Epps** and **Pat Morgan. Stanley Zanitis** was in charge of golf arrangements while refreshments were in charge of **Charles Scoville** and **Jess Burley.**

Included in the picnic were golf, games, refreshments and food. Activities started at 9:00 am with golf followed by a picnic at noon and a dinner at 5:30. A prize drawing was also held.

St. Louis Chapter

Holds Annual Picnic

■ Approximately 115 members and guests attended the annual picnic. One of the features was the foundrymen vs suppliers softball game, with the foundrymen winning.

Northern California
Presents Apprentice Award

■ Conrad Rost, Empire Foundry, Oakland, Calif., has received the first Andrew Ondreyco award presented to the outstanding foundry apprentice in the San Francisco Bay area. The award consists of $100 in cash, an individual plaque and an inscription on a perpetual trophy to be kept on display at the International Molders and Foundry Workers Union Hall.

The award, to be an annual affair, has been made possible by an anonymous donor in the honor of Andrew Ondreyco who was active in the Bay area foundry activities and Chairman of the Northern California Chapter, 1947-48.

Sixty-three apprentices competed for the award based on grades in school work, interviews with individuals and their immediate supervisors.

Judges were Clayton Russell, Phoenix Iron Works, Oakland, Calif., chairman of the Apprentice Committee; Michael Ginty, Vulcan Foundry, Oakland, Calif.; and Lane Currie, H. C. Macaulay Foundry, Berkeley, Calif.

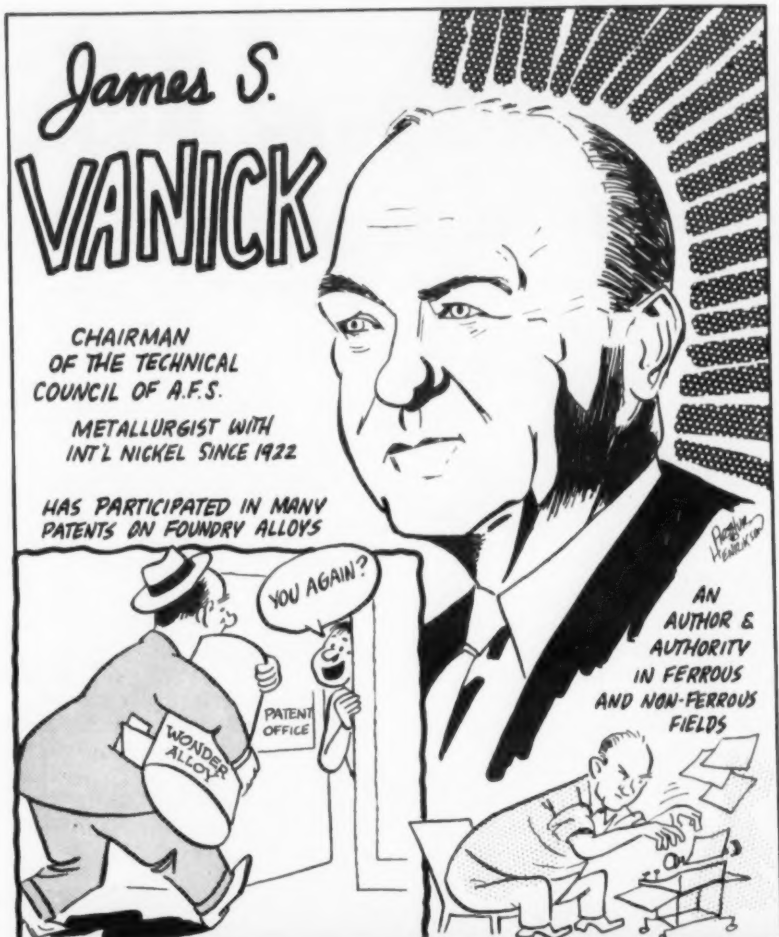
Presentation of the award was made by Harold Hirsch, American Manganese Steel, Oakland, Calif., retiring President of the Northern California Chapter.

Western Michigan
Holds Annual Picnic

■ More than 750 foundrymen attended the annual picnic which included baseball, horseshoes, golf, dinner and entertainment.

Chapter Chairman J. Joseph Cannon and Dave Jacobson were cochairmen of the picnic committee. Others on the committee were Horace Deane, Gordon Robidoux, Paul Antol, Bernard Boelkins, Bill Tuthill, George Gokey, John DeGroot, Max Ryefield, Charlie Lundquist, Harold Westbrook and Ed Bumke.—*Dan Connell.*

Old timers attending the Western Michigan Chapter picnic were A. E. Jacobson, Sr., one of the founders of Grand Haven Brass Foundry, Grand Haven, Mich.; Burton Hanson, retired secretary with 50 years service with Challenge Machinery Co., Grand Haven, Mich.; and George W. Cannon, Sr., one of the founders of Campbell, Wyant & Cannon Foundry Co., Muskegon, Mich.



Personalities

William I. Englehart, Cleveland District Advertising Manager, MODERN CASTINGS, is now serving as Northeastern Ohio Chapter Publicity Chairman.

Each month the **Central Indiana Chapter** features a display of castings from the chapter giving members a picture of the foundry activities in this area.

continued on page 106

Foamed Epoxy Resin . .

a new material for pattern makers

Armand G. Winifield / *Product Design Engineer*
DeBell & Richardson, Inc.
Hazardville, Conn.

Another new material for the patternmaker has been created by reacting epoxy resins with a foaming agent. The result is a strong light-weight substitute for wood with exceptional dimensional stability and resistance to attack by acids, alkalies, solvents and other chemicals. Yet in spite of its rugged properties the material is extremely easy to handle.

Tests have been made by pattern shops in which every tool in the shop from penknife to lathe or milling machine has been used with equal ease. In all cases it made no difference whether the tool was sharp or dull, the desired effect was achieved.

Illustrations **1**, **3**, and **4** are patterns produced from the new material. Illustrations **2** and **5** are castings made from the epoxy patterns.

Because of its fine, uniform cellular structure and complete freedom from grain this new material can be carved or machined in any direction leaving a good surface on which a finishing or splining coat may be applied if necessary. Illustration **3** is a foamed epoxy pattern splined with epoxy.

In the case of patterns for sand castings it is sometimes unnecessary to seal the porous finish on the pattern if a smooth as-cast finish is not required.

Pieces of the plastic material can be cemented effectively by the use of epoxy or polyester cements. These same cements can also be used to fill the minute cellular cavities on the surface of a pattern made from foamed plastic. Plaster also makes a good surface coat for sealing pores. Almost any paint other than a water color can likewise be applied to the surface. Coatings can be either lightly sanded or left rough.

Room temperature properties of the plastic are given in the following table:

Density lb/cu. ft.	Compressive Strength psi	Compressive Modulus $\times 10^3$ psi	Flexural Strength psi	Flexural Modulus $\times 10^3$	Tensile Strength psi	Shear Strength psi	Heat Distortion (20 psi load) Degree F
5	90	2.1	210	2.7	51		
10	260	8.0	420	8.3	180		194
13	440	14.3	570	15.0	360	324	
20	1080	27.0	940	32.0	650		

Under loads at elevated temperatures it exhibits a yield point around 212 F. At higher temperatures this material becomes rubbery in nature but the deformation is recoverable.

Moderate temperature changes and humidity do not affect dimensional stability of patterns made from this material. However, for applications which are extremely critical or where the material will be used at somewhat elevated temperatures, it is desirable to relieve stresses in the foam by post-curing* prior to final tooling, machining and /or surface coating. Or it can be furnished post-cured or preshrunk where customer shop facilities are inadequate for this treatment.

Patternmakers may be interested to know that this lightweight epoxy can be heated to a temperature of around 300 F and compressed at that temperature to thicknesses up to one-sixth of the original block (6-in. thickness can be compressed to 1-in. thickness). When the part is cooled to room temperature it remains in the compressed state but the density has changed from its original density to one of, in this case, six times. The compressed shape will remain constant until the block is reheated at a temperature slightly over that of boiling water. This causes a release of the material and it will expand to almost 100 per cent of its original thickness.

This thermosetting prefoamed epoxy material is now available in planks, sheets or as blocks up to 12x24x96 in. and in densities ranging from 5 to 20 lb per cubic foot.

Prefoamed epoxy resin is a versatile material which should find numerous applications suited to the needs of a patternmaker, foundryman artisan and engineer.

*Preheating can be done at lower temperatures depending upon the thickness of the part. For example, a 1-in. section can be preshrunk at 250 F for 1 hr whereas a 6-in. section might take 9 to 12 hrs. The higher the temperature, however, up to 350 F, the faster the preshrinkage will occur in each section.

■ To obtain single additional copies of this article, circle E, Reader Service card, page 7-8.

ZINC DIE CASTINGS TRIM CARS AND COSTS

Ford Motor Co. puts from 86 to 99 lb of zinc into each 1958 Edsel for functional use as well as decoration, such as this hood ornament.

The 1958 Edsel, demonstrates the trend toward increasing use of zinc die castings for a variety of functional and decorative parts.

According to the Ford Motor Co., from 86 to 99 lb of zinc die castings are used on each of the different Edsel models.

Edsel engineers say that "Zinc die castings were chosen for reasons of economy and ease of manufacture consistent with the adaptability of zinc die castings for the particular function served."

Zinc die castings are used in many important functional parts including fuel pump, instrument panel cluster, door handle assemblies, seat adjusting mechanism, horn ring assembly, various brackets and handle assemblies, windshield wiper parts. The cars also use zinc for ornamental parts including the radiator grille, lamp assemblies, rear seat radio speaker grille assemblies, and a variety of ornaments, trim escutcheons, nameplates, bezels and moulding parts. Crank-like zinc alloy window regulator handles are cast in multiple-cavity dies quickly and economically.

Optional equipment such as power steering, power brakes, automatic transmission assemblies, heater and air conditioner parts all take advantage of zinc die casting precision, versatility, toughness and general economy.

Typical Zinc Die Castings in the Edsel

Part Name	Lb	Qty/Car
Handle Assy., Parking Brake	0.14	1
Horn Ring Assy., Blowing	1.15	1
Bracket Assy., Steering Column	0.48	1
Bracket, Steering Column		1
Adapter, Luggage Compt. Dr. Lock Switch Mtg.	0.0527	1
Grille, Radiater	6.75	2
Bezel Ignition Switch	0.033	1
Door, Headlamp Inner	1.24	2
Door, Headlamp Outer	1.25	2
Lamp Assy., Rear Outer	2.5375	2
Lamp Assy., Rear Outer	2.6147	2
Lamp Assy., Rear Inner	3.825	2
Lamp Assy., Rear (Station Wagon)	5.310	2
Lamp Assy., Rear (Station Wagon)	5.005	2
Lamp Assy., Rear Inner	3.4943	2
Door Assy., Courtesy Lamp	0.215	2
Nut, Seat Reg. Control Switch Bezel		
Nut, Luggage Compt. Door Lock	0.0736	1
Handle, Top Control	0.14	1
Bezel, Top Control Handle	0.01	1
Spacer, Top Control Switch	0.01	1
Knob Assy., Speed Warning Control	0.050	1
Dial, Speed Warning Control	0.044	1
Bezel, Speed Warning Control	0.020	1
Cover Assy., Speed Warning Control Opening	0.062	1
Plate Front Fender Name Corsair	0.1147	2
Plate Front Fender Name Citation	0.1147	2
Plate Front Fender Name Villager	0.156	2
Plate Front Fender Name Ranger	63 grams	2
Plate Front Fender Name Pacer	65 grams	2
Ornament Assy., Front Fender Side		1

Part Name	Lb	Qty/Car
Plate Hood Top Ornament Retaining	0.032	1
Ornament Assy., Hood Top	0.1744	1
Moulding, Hood Front	0.69	1
Disc, Radio Tone Control	0.130	2
Bezel Radio Control	0.40	1
Grille Assy., Radio Rear Seat Speaker	0.3125	1
Grille Assy., Radio Rear Seat Speaker	0.408	1
Bezel Assy., Parking Brake Release	0.040	1
Moulding, Radiator Grille Opening Panel	0.59	2
Moulding, Instr. Panel Pad Ret. Inner	0.09	1
Extension Assy., Rear Door	6.45	2
Handle Assy., Rear O/S Door	1.098	2
Moulding, Quarter O/S Finish	0.18	2
Cover Assy., Back-up Lamp Opening		1
Moulding, Upper Back Panel	1.667	1
Handle Assy., Luggage Compt. Door	2.275	1
Ornament, Roof Side	0.60	2
Moulding, Instrument Panel Upper Covering	0.06	2
Plate Instr. Panel Name Ranger	0.048	1
Moulding, Instr. Panel Pad Ret. Inner	0.11	1
Moulding, Instr. Panel Pad Ret. Inner	0.08	1
Handle Assy., Window Regulator		4
Handle Assy., Rear Door O/S	0.670	2
Letters, Body Side Edsel	0.024	10
Moulding Assy., Luggage Compt. Door	1.536	1
Handle Assy., Luggage Compt. Door		1
Ornament, Lift Gate	1.12	1
Handle Assy., Front Seat Track Adj.		1
Handle Assy., Tail Gate	1.99	1
Clip Assy., Visor Arm	0.103	1
Moulding, Luggage	2.449	1
Plate Instr. Panel Name Villager	0.05	1

Upward Trend

In their specification and use of zinc, Edsel engineers are attesting to rapidly expanding industry experience with the material. During the last five years the growth in the use of zinc die castings by the automotive manufacturers has been spectacular. One major car manufacturer reported that since 1952 their use of zinc die castings has jumped from 32 to 59 lb per car. Another manufacturer stated that more than 140 lb of zinc were used in its 1957 model, and its 1958 model carries even more.

Decorative parts are generally die cast of S.A.E. zinc alloy 903 and are chromium plated, painted, or plated and painted. Ease of polishing, painting, and availability of zinc die castings in complex shapes and thin sections to close tolerances are among the reasons for their industry-wide use in appearance parts.

Functional parts are frequently cast from zinc alloy S.A.E. 925 which is identical to S.A.E. 903 but with copper added. Most automobile manufacturers use this alloy for carburetors and fuel pumps where its high impact strength, low porosity, and good holding strength in tapped holes are crucial. Both for decorative and functional parts zinc die castings are designed to minimize machining operations, substitute single die case pieces for what in another process would be an intricate assembly, conserve material and improve appearance. Result: simplified assembly problems, better fits, life time durability, and the smooth, sleek forward look of today's modern car.

Chapter News

Continued from page 103

afs chapter meetings

OCTOBER

All Canadian Foundry Conference . . Oct. 16-17 . . Royal Connaught Hotel, Hamilton, Ont.

Birmingham District . . Oct. 10 . . Tutwiler Hotel, Birmingham, Ala. . . T. C. Alford, Tri-State Sand Co., *"Coreroom Practice."*

British Columbia . . *See Northwest Regional Foundry Conference.*

Canton District . . Oct. 2 . . Swiss Club, Canton, Ohio . . Mr. Vaughn, Wheelabrator Co., *"Reducing Blast Cleaning Costs" and Film of Shot Manufacture.*

Central Illinois . . Oct. 6 . . Vonachen's Junction, Peoria, Ill.

Central Indiana . . Oct. 6 . . Athenaeum Turners, Indianapolis.

Central Michigan . . *See Michigan Regional Foundry Conference.*

Central New York . . Oct. 10 . . Mark Twain Hotel, Elmira, N. Y. . . W. C. Wheadon, Syracuse University Research Institute, *"Nondestructive Testing of Castings."*

Central Ohio . . Oct. 13 . . Seneca Hotel, Columbus, Ohio.

Chesapeake . . Oct. 24 . . Engineers' Club, Baltimore, Md. . . G. F. Watson, American Brake Shoe Co., *"Casting Defects Caused by Sand."*

Chicago . . Oct. 6 . . Chicago Bar Association, Chicago . . C. A. Sanders, American Colloid Co., *"What European Foundrymen Are Doing."*

Cincinnati District . . Oct. 13 . . Engineers' Club, Dayton, Ohio . . E. F. Price, Dayton Malleable Iron Co., *"Cleaning and Finishing."*

Connecticut . . Oct. 24 . . General Dynamics Corp., Electric Boat Div., Groton, Conn., *Plant Visitation.*

Detroit . . Oct. 9 . . Hotel Wolverine Detroit . . *Ferrous Group*: M. H. Horton, Deere & Co., *"Water-Cooled Cupolas — Construction, Operation & Controls";*

Non-Ferrous Group: "Low Frequency Induction Melting."

Eastern Canada . . **Oct. 3** . . Mount Royal Hotel, Montreal, Que. . . E. E. Woodliff, Foundry Sand Service Engineering Co., *"Evaluation of Sand Additives & Properties."*

Eastern New York . . **Oct. 21** . . Panetta's Restaurant, Menands, N. Y.

Metropolitan . . **Oct. 6** . . Essex House, Newark, N. J. . . G. F. Watson, American Brake Shoe Co., *"Causes & Correction of Casting Defects Due to Sand."*

Mexico . . **Oct. 20** . . Av. Chapultepec 412, Mexico D.F., Mexico . . E. Aleman, Metalurgica Almena *"Molding Clay & Sands."*

Michiana . . **Oct. 13** . . Fehlberg, 352 Lake Shore Drive, Stevensville, Mich. . . A. Dorfmueller, Jr., Archer-Daniels-Midland Co., *"Which Core?"*

Michigan Regional Foundry Conference . . **Oct. 15-16** . . University of Michigan, Ann Arbor, Mich.

Mid-South . . **Oct. 10** . . Claridge Hotel, Memphis, Tenn.

Mo-Kan . . **Oct. 3** . . Fairfax Airport, Kansas City, Kans.

New England . . *See New England Regional Foundry Conference.*

New England Regional Foundry Conference . . **Oct. 17-18** . . Massachusetts Institute of Technology, Cambridge, Mass.

Northeastern Ohio . . **Oct. 9** . . Tudor Arms Hotel, Cleveland.

Northern California . . **Oct. 13** . . Red Rooster, Oakland, Calif. . . W. Franck, Carborundum Co., B. Christensen, Gladding McBean & Co., and R. Goodell, E. J. Bartells Co. of Calif., *"A Refractories Night."*

Northwest Regional Foundry Conference . . **Oct. 31-Nov. 1** . . Multnomah Hotel, Portland, Ore.

Northwestern Pennsylvania . . **Oct. 27** . . Amity Inn, Erie, Pa. . . A. H. Homberger, International Automation Corp., *"The 'Buhrer' Automated Molding & Pouring Method."*

Ontario . . *See All Canadian Regional Foundry Conference.*

Oregon . . *See Northwest Regional Foundry Conference.*

Philadelphia . . **Oct. 10** . . Engineers' Club, Philadelphia . . Dr. J. Creese, Drexel Institute of Technology, *"The Common Ground of Industry & Education."*

Piedmont . . *No Meeting.*

Pittsburgh . . **Oct. 20** . . Hotel Webster Hall, Pittsburgh, Pa. . . O. C. Bueg, Arrow Pattern & Engineering Co., *"Pattern Epoxy."*

Purdue Metal Castings Conference . . **Oct. 30-31** . . Purdue University, West Lafayette, Ind.

Quad City . . **Oct. 20** . . LeClaire Hotel, Moline, Ill. . . M. Bock, Exomet, Inc., *"Exothermic & Insulating Materials."*

Rochester . . **Oct. 7** . . Manger Hotel, Rochester, N. Y.

Saginaw Valley . . **Oct. 2** . . Fischer's Hotel, Frankenmuth, Mich. . . W. G. Gude, Penton Publishing Co., *"The Future of the Foundry Industry."*

St. Louis . . **Oct. 9** . . Edmond's Restaurant, St. Louis . . R. L. Gilmore, Superior Steel & Malleable Castings Co., *"Casting Design."*

Southern California . . **Oct. 10** . . Rodger Young Auditorium, Los Angeles . . A. B. DeRoss, Kaiser Aluminum & Chemical Sales, Inc., *"Kaiser Aluminum's New Alloy X-357."*

Tennessee . . **Oct. 24** . . Patten Hotel, Chattanooga, Tenn. . . H. J. Weber, AFS, *"Impact of Air Pollution Laws on Foundries."*

Texas . . **Oct. 17** . . Texas Hotel, Ft. Worth, Texas . . J. Dee, Dee Brass Foundry, Moderator, Panel Discussion *"Non-Ferrous Practice."*

Timberline . . **Oct. 13** . Oxford Hotel, Denver, Colo. . . *Officers' Night.*

Toledo . . **Oct. 1** . . Heather Downs Country Club, Toledo, Ohio . . D. L. Colwell, Apex Smelting Co., *"Die Casting & Permanent Mold Advances."*

Tri-State . . **Oct. 10** . . Wilder's Restaurant, Joplin, Mo.

Twin City . . **Oct. 14** . . Jax Restaurant, Minneapolis . . M. P. Schroeder, Prospect Foundry Co., L. E. Perkins, Northern Malleable Iron Co., J. Wallfred, Minneapolis Electric Steel Castings Co., and C. W. Sundberg, Minneapolis Electric Steel Castings Co., Moderator, *"CO^2 Symposium."*

Utah . . **Oct. 6** . . Provo, Utah . . R. J. Franck, Superior Steel & Malleable Castings Co., *"Casting Design from Stress Analysis."*

Washington . . *See Northwest Regional Foundry Conference.*

Western Michigan . . **Oct. 6** . . Spring Lake Country Club, Spring Lake, Mich.

Western New York . . **Oct. 3** . . Hotel Sheraton, Buffalo, N. Y. . . W. J. Mahoney, Senior State Senator. *"State Legislation Benefiting the Foundry Industry."*

Wisconsin . . **Oct. 10** . . Schroeder Hotel, Milwaukee . . W. G. Ferrell, Auto Specialties Mfg. Co., *"The Future of the Foundry."*

NOVEMBER

Birmingham District . . **Nov. 14** . . Jefferson Davis Hotel, Anniston, Ala.

British Columbia . . **Nov. 21** . . Leon's, Vancouver, B. C. . . D. L. Colwell, Apex Smelting Co., *"Die and Permanent Mold Casting."*

Canton District . . **Nov. 6** . . American Legion Hall, Massillon, Ohio . . D. E. Krause, Gray Iron Research Institute, *"Research in the Foundry."*

Central Illinois . . **Nov. 3** . . American Legion Hall, Peoria, Ill.

Central Indiana . . **Nov. 3** . . Athenaeum Turners, Indianapolis.

Central Ohio . . **Nov. 10** . . Seneca Hotel, Columbus, Ohio.

Chicago . . **Nov. 3** . . Chicago Bar Association, Chicago . . *Ferrous Group: "Basic Quality Control"; Non-Ferrous Group: Panel "Foundry Scrap–Causes and Cures"; Pattern Group:* Z. Madacey, Beardsley & Piper Div., Pettibone Mulliken Corp., *"Core Blowing."*

Metropolitan . . **Nov. 3** . . Essex House, Newark, N. J. . . C. A. Sanders, American Colloid Co., *"What European Foundries Are Doing."*

Mo-Kan . . **Nov. 7** . . Fairfax Airport, Kansas City, Kans.

Piedmont . . **Nov. 7** . . John Marshall Hotel, Richmond, Va. . . D. L. LaVelle, American Smelting & Refining Co., *"Aluminum Casting Defects & Their Correction."*

Rochester . . **Nov. 11** . . Manger Hotel, Rochester, N. Y.

Saginaw Valley . . **Nov. 6** . . Fischer's Hotel, Frankenmuth, Mich. . . *Ferrous Group:* H. H. Wilder, Vanadium Corp., *"Practical Inoculation of Gray Iron"; Non-Ferrous Group:* J. Chini, Sperry Gyroscope Co., *"High Quality Molding Processes"; Steel Group:* H. F. Bishop, Exomet, Inc., *"Gating & Risering of Steel"; Permanent Mold & Die Casting Group:* J. Atols, Atols Tool & Mold Corp., *"Shaw Process."*

Twin City . . **Nov. 18** . . Jax Restaurant, Minneapolis . . *Joint Meeting with American Society for Metals.*

Utah . . **Nov. 12** . . Salt Lake City . . D. L. Colwell, Apex Smelting Co., *"Die and Permanent Mold Castings."*

Western Michigan . . **Nov. 3** . . Elks Club, Ludington, Mich.

Western New York . . **Nov. 7** . . Sheraton Hotel, Buffalo, N. Y. . . O. J. Myers, Reichhold Chemicals, Inc., *"Self Curing Oils."*

Wisconsin . . **Nov. 14** . . Schroeder Hotel, Milwaukee . . *Sectional Meeting.*

let's get personal

C. A. Haag . . . has been appointed by Ainsworth-Precision Div., Harsco Corp., Detroit, to head its Eastern Division's production facilities. He has been with the company and its predecessor firm, Precision Castings Co., for 33 years, beginning as a die shop apprentice, and advancing to his former position as chief engineer.

C. R. Gebel . . . sales representative in the Pittsburgh area for Electrode Div., Great Lakes Carbon Corp., New York, is now manager of the company's new branch in Pittsburgh. A member of the American Institute of Mining & Metallurgical Engineers, Inc., he joined his present company in 1954 as sales representative.

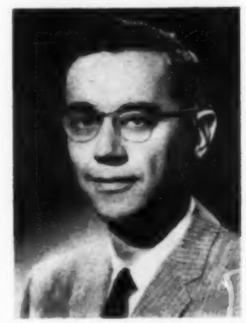
J. W. Harr . . . replaces **J. H. Harrington** as assistant-regional manager at Chicago for the Pure Carbonic Co., New York. Harrington has been transferred to the eastern region. Harr joined Pureco in 1952 and has been warehouse manager in Cleveland and Detroit.

W. P. James . . . technical manager, WaiMet Alloys Co., Detroit, addressed the Investment Casters Society of California. His topic was *"The Application of Vacuum Induction Melting and Casting to the Investment Casting Process."* The vacuum melting technique has been widely used in research efforts to obtain high purity metals and alloys for study of properties. James specialized in the development of high-temperature alloys and special high-vacuum furnaces for processing the alloys.

R. A. Lowe . . . is the new sales manager, Baldwin-Lima-Hamilton SR-4 Products Group, according to a release from the company's Electronic & Instrumentation Division in Waltham, Mass. He will be responsible for the marketing of SR-4 strain gages, transducers, instrumentation and systems.

A. M. Klinger . . . who served as sales manager for Ingersoll Kalamazoo Div., Borg-Warner Corp., Kalamazoo, Mich., has been named the company's sales manager of materials handling products. He will be responsible for the entire field-sales force.

R. P. Dunn . . . has left U. S. Reduction Co., East Chicago, Ind., where he served as director of metallurgy, to accept employment with Lindberg Melting Furnace Div., Lindberg Engineering Co., Chicago.



R. P. Dunn

He is the new technical director for the company, and will be in charge of technical development of the firm's line of melting and holding furnaces for aluminum, brass, bronze, tin and other non-ferrous metals. Dunn is currently secretary, Executive Committee, Die Casting and Permanent Mold Div., American Foundrymen's Society. **L. A. Shea** has been appointed district sales manager of the company's Pennsylvania office.

B. M. Ronay . . . is the new consultant in welding technology to Gulton Industries, Inc., Metuchen, N. J. Ronay's services will concentrate chiefly on welding research of the company's Advanced Development and Systems Dept. The Secretary of the Navy appointed him to his previous position, held 25 years, as superintendent of the U. S. Naval Experiment Station, Annapolis, Md. He holds over 25 patents in his specialty and is the recipient of the Distinguished Meritorious Award from the American Weld-

ing Society for his outstanding work during the past 35 years.

William Rosenquest . . . has joined the metal sales staff, New Jersey Zinc Co., New York. He will sell the company's slab zinc, zinc alloys, rolled zinc and metal powders.

H. R. Hiller . . . has been appointed assistant district sales manager of Harbison-Walker Refractories Co., Pittsburgh, Pa., Chicago district. Hiller has been in refractories sales work for more than 30 years and joined this company in 1955.

R. L. Kulp . . . former chief draftsman, has been named sales engineer for Reading Crane and Hoist Corp., Reading, Pa. He has been with the company since 1923 and will cover sales area east of the Mississippi.

Robert Williams . . . former works manager, Gardner-Denver Co., Quincy, Ill., has been promoted to general plant advisor. **A. J. Kathmann,** assistant works manager, will take his place. **G. A. Schumacher,** formerly superintendent of LaGrange, Mo. foundry, became manager of foundry operations, with headquarters in Quincy. His former position will be filled by **E. J. Brown. J. A. Van Doorn,** in addition to his duties as manager of facilities, has also been placed in charge of Gardner-Denver's maintenance divisions.

J. A. McGuire . . . has been elected executive vice-president, Thor Power Tool Co., Chicago, to share a twin office with **W. A. Nugent** who has held a similar position for the past 10 years. **J. A. Lind,** officer for 16 years and currently treasurer and vice-president in charge of finance, was elected a director. **N. C. Hurley, Jr.,** president, stated: "McGuire, who as vice-president for five years, has handled the company's labor policy and other executive functions, will work largely with integrating the company's five subsidiary plants.

P. P. Waldeck . . . export manager, Shallway International Corp., Palo Alto, Calif., foreign marketing consultants, is on a two-month Latin American tour. Objective of trip is to select distributors for clients. His company manufactures refractory guns for patching and lining foundry cupolas, shell molding equipment and supplies and other technically advanced foundry equipment.

Build an idea file for plant improvements. Reader Service Cards, page 7-8 will bring more information . . .

for the asking

Foundry operations . . . in large permanent mold and die casting foundry described in brochure. *Monarch Aluminum Mfg. Co.*
Circle No. 942, Page 7-8

Blasting machines . . . portable, 100-1200-lb capacities, covered in brochure. *Brennen, Bucci & Weber, Inc.*
Circle No. 943, Page 7-8

C-clamp . . . with new design including swivel pads guaranteed never to come off. Catalog available. Use circle number below. *Wilton Tool Mfg. Co.*
Circle No. 944, Page 7-8

Conveyor belt . . . fastening, features counter-sunk design. Described in bulletin. *Crescent Belt Fastener Co.*
Circle No. 945, Page 7-8

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Micro scale . . . permitting quick, accurate settings for dividers, trammels or compasses—demonstrated in brochure. *Trico Machine Products Corp.*
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Surface coating . . . guards castings or equipment against destruction by acids and caustics. Illustrated in folder. *Hallemite Mfg. Co.*
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Compressed air . . . dryers, heatless, self-activating models described in 12-p bulletin. Designed to prevent moisture fouling of molds, furnaces, etc. *Van Products Co.*
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Hydraulic boom . . . unit with 2500-lb capacity. Features telescoping construction. Request 4-p folder. *Vanguard Engineering Co.*
Circle No. 950, Page 7-8

Roof coating . . . fibreglass material for coating effective at temperatures to 140 F. Applications illustrated in 4-p folder. *Garland Co.*
Circle No. 951, Page 7-8

Powdered acid inhibitor . . . described in technical bulletin. Reportedly effective with ferrous and non-ferrous alloys. *Sole Chemical Corp.*
Circle No. 952, Page 7-8

Spray-lubricate . . . unit for use on dies, molds, hammers, etc., presented in folder. *Renite Co.*
Circle No. 953, Page 7-8

Vacuum melting . . . furnace, melt capacity of 50 lb, described in data sheet. *F. J. Stokes Corp.*
Circle No. 954, Page 7-8

Lubricants . . . solid film type, described in catalog. Includes eight lubricants and their applications. *Electrofilm, Inc.*
Circle No. 888, Page 7-8

Manifolds . . . for distributing gases such as CO_2. Request 20-p catalog. *Air Reduction Sales Co.*
Circle No. 889, Page 7-8

Magnet pulleys . . . for scrap or castings separation in belt-conveyor system. Booklet mailed on request. *Stearns Magnetic Products.*
Circle No. 890, Page 7-8

Electrical trolley . . . system said to provide 100 per cent safety described in bulletin detailing components and accessories. *U-S Electric Mfg. Co.*
Circle No. 891, Page 7-8

Electric trucks . . . designed for narrow-aisle operations presented in bulletin. *Raymond Corp.*
Circle No. 892, Page 7-8

Grinding and polishing . . . equipment illustrated in handy "pocket edition" booklet. *Grinding & Polishing Machinery Corp.*
Circle No. 893, Page 7-8

Table positioning . . . automatically, for speeding operations such as drilling, welding, etc.—described in folder. *Electronic Control Systems, Div. Stromberg-Carlson.*
Circle No. 894, Page 7-8

Presser boards . . . made of cherry lumber pictured in bulletin. Said to pay for themselves in castings they save. *Adams Co.*
Circle No. 895, Page 7-8

Microstructure . . . of gray iron castings illustrated in 12-p booklet showing micrographs of castings with from 31,500 to 63,000 psi. To obtain circle number below. *Herbert A. Reese & Associates.*
Circle No. 896, Page 7-8

Crane scale . . . hydraulic, for capacities, 1000-20,000 lb, featured in 4-p

bulletin. Eliminates need for central weighing station. *Martin-Decker Corp.*
Circle No. 897, Page 7-8

Materials handling . . . manual equipment standards (three new ones) available. Platform trucks, all-rubber wheels and semi-pneumatic tires. *Caster and Floor Truck Mfg. Assoc.*
Circle No. 898, Page 7-8

Plastic refractory . . . reportedly slag-resistant illustrated in 4-p bulletin. Protects ladles, spouts and cupolas. *North American Refractories Co.*
Circle No. 899, Page 7-8

Shaw Process . . . explained in bulletin which illustrates applications of precision casting technique. *Shaw Process Development Corp.*
Circle No. 900, Page 7-8

Drum lift . . . unit, one-man operation, portrayed in bulletin. *Sterling, Fleischman Co.*
Circle No. 901, Page 7-8

Work gloves . . . utilizing rubber in various forms to facilitate gripping illustrated in booklet. *Hood Rubber Co.*
Circle No. 902, Page 7-8

Materials handling . . . equipment, described in 21-p booklet. Illustrates materials handling in plant. *Berger Div., Republic Steel Corp.*
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Machine welding . . . department function and services outlined in 6-p brochure. *Air Reduction Sales Co.*
Circle No. 904, Page 7-8

Ultrasonic cleaning . . . applications and principles explained in 24-p booklet. *Branson Ultrasonic Corp.*
Circle No. 905, Page 7-8

Storage problems . . . solved in well-illustrated folder. Features stock storage. *Jarke Mfg. Co.*
Circle No. 906, Page 7-8

Electrode . . . positioning, accomplished automatically. Illustrated in 8-p booklet featuring electrode arms and clamps. *Whiting Corp.*
Circle No. 907, Page 7-8

Pipe . . . specification sheet covers A.S. T.M. specifications relative to testing, weight, diameter, thickness and other stipulations. *Crane Co.*
Circle No. 908, Page 7-8

Floor patch . . . material for concrete floors described in 2-p bulletin. *Walter Maguire Co.*
Circle No. 909, Page 7-8

Industrial tool . . . catalog with illustrations and specifications for company's portable and air tool equipment. *Thor Power Tool Co.*
Circle No. 910, Page 7-8

Front-end loader . . . details in brochure, with line drawing pointing out features and advantages. *Frank G. Hough Co.*
Circle No. 911, Page 7-8

Lift truck . . . bulletin. Designed for all-pupose, full-time foundry use, unit said to provide new low in mainte-

nance. *Beardsley & Piper Div., Pettibone Mulliken Corp.*
Circle No. 912, Page 7-8

Cobalt-base alloys . . . properties described in two booklets. Alloys used mainly for investment castings. *Haynes Stellite Co., Div. Union Carbon Corp.*
Circle No. 913, Page 7-8

Hand lift . . . truck bulletin features selector chart designed to facilitate selection of proper unit for specific operations. *Lewis-Shephard Products, Inc.*
Circle No. 914, Page 7-8

Pearlitic malleable . . . castings bulletin describes properties and lists specifications. *American Malleable Castings Co.*
Circle No. 915, Page 7-8

Monolithic refractory . . . material for construction of walls and arches without forms graphically portrayed in brochure. *Refractory & Insulation Corp.*
Circle No. 916, Page 7-8

Indicating controlling . . . pyrometer bulletin, 6 pp, explains operation, lists specifications and gives wiring diagrams. *Illinois Testing Laboratories, Inc.*
Circle No. 917, Page 7-8

Technical publications . . . catalog outlines books and manuals which include techniques and processes pertinent to the metalcastings industry. *American Foundrymen's Society.*
Circle No. 918, Page 7-8

Die casting . . . alloys covered in revised bulletin listing properties of aluminum, magnesium and zinc alloys. *Apex Smelting Co.*
Circle No. 919, Page 7-8

Flame-cutting . . . folder, 12 pp, describes how the proper nozzle selection and construction can greatly reduce cost. *Linde Co.*
Circle No. 920, Page 7-8

Non-ferrous . . . casting folder describes company's facilities and services. Small and medium castings produced in job lot and mass production quantities. *Non-Ferrous Casting Co.*
Circle No. 921, Page 7-8

Compressors . . . heavy-duty, high pressure, stationary type, featured in 8-p bulletin. *Joy Mfg. Co.*
Circle No. 922, Page 7-8

Industrial insulations . . . catalog presents properties and specifications of complete line in 20-p booklet. *Baldwin-Hill Co.*
Circle No. 923, Page 7-8

Materials handling . . . system engineered for flexibility to meet changing in-plant operations. Illustrated and described in case-history report. *Elwell-Parker Electric Co.*
Circle No 924, Page 7-8

Metal castings . . . uses and advantages pointed out in question and answer form in 28-p booklet covering malleable iron, pearlitic malleable iron, gray iron,

aluminum and magnesium. *Dayton Malleable Iron Co.*
Circle No. 925, Page 7-8

Foundry flasks . . . selection and maintenance covered in 24-p booklet. *Sterling National Industries. Inc.*
Circle No. 926, Page 7-8

Sand cooling . . . problem presented and solution offered in pamphlet. *Beardsley & Piper Div., Pettibone Mulliken Corp.*
Circle No. 927, Page 7-8

Roller chain . . . engineering data book, 154 pp, said to be most comprehensive ever written on precision steel roller chains and sprockets. *Link-Belt Co.*
Circle No. 928, Page 7-8

Epoxy compounds . . . announced in 3-p bulletin. Liquid epoxy-base resins can be used with standard hardeners. *Houghton Laboratories, Inc.*
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Electric vibrators . . . with variable control of power explained in 12-p brochure. Applications shown. *Syntron Co.*
Circle No. 930, Page 7-8

Ball-bearing trolleys . . . booklet contains 20 pp of data on types and sizes of trolleys available. *Link-Belt Co.*
Circle No. 931, Page 7-8

training films

■ The following list of motion pictures and film strips will prove useful in educating your personnel to better perform their jobs. Circle the appropriate number on the Reader Service Card (page 7-8) for complete information regarding these films. Items indicate whether films are available free of charge, by rental or by purchase only.

Pointing the Way . . . Concentrates on production of investment castings for aircraft and industrial applications. Sixteen mm, color, sound, 20 min, free. *Misco Precision Casting Co.*
Circle No. 932, Page 7-8

Of Time and Salesmen . . . Illustrates importance to salesman of making the best possible use of his selling time, outlining a plan. Sixteen mm, sound, free. *Dun & Bradstreet, Inc.*
Circle No. 933, Page 7-8

Mold and Core Ventilation . . . One of a series of films covering foundry technique. Thirty-five mm filmstrip, black and white, rental. *Educational Productions, Ltd.*
Circle No. 934, Page 7-8

Let's Face It . . . Two films designed to stimulate discussion on the importance of good employer-employee relations, emphasizing intelligent cooperation. Sixteen mm, sound, 2 reels, 30 min, rental. *American Economic Foundation.*
Circle No. 935, Page 7-8

Target: U.S.A. . . . Plant defense and protection in this atomic age are outlined for management. Demonstrates what to do and how to do it. Sixteen mm, black and white or color, sound 20 min, 2 reels, rental. *Cornell Film Co.*
Circle No. 936, Page 7-8

foundry trade news

INVESTMENT CASTING INSTITUTE . . . held a special three-day technical session in Muskegon, Mich. and presented the latest in technical information to their members. Five papers from industry leaders on experiences with an investment casting shell were presented and a round-up report on development of ceramic shells was moderated by Dr. Jack Keverian, General Electric Co. Papers included: *The Fundamental Aspects of a Ceramic Shell for Precision Castings*, by K. D. Scheffer, General Electric; *Alumina Shell Molds for Investment Castings*, by F. C. Quigley, Rodman Laboratory, Watertown Arsenal. Following these reports, Ted Operhall, Misco Precision Castings Co.; Dr. Raymond Reuter, National Aluminate Corp. and J. D. Pisula, Cohart Refractories Co. discussed experiences in making investment castings in a ceramic shell. Other presentations included a report from J. K. Dietz, Chance Vought Aircraft who pointed out that: "In looking to the future for airframe and missile applications there is an $125 million market in this area alone for investment castings if they can be produced with the following qualifications:

Length – 36" to 48"
Minimum section – 0.1 to 0.08
Tensile strength – 260,000 psi
Yield strength – 210,000 psi
Elongation – 4% minimum

A ceramic shell for investment casting appeared to be the key to cost reduction, increased quality and larger sizes for precision investment castings.

Examining Misco's new "Monoshell" left to right (seated) are: F. H. Bennett, Pratt & Whitney; Dr. R. A. Flinn, University of Michigan; Rene Roques, Microfusion, Paris, France; C. R. Whittemore, Deloro-Stellite; Dr. Jack Keverian, General Electric Co.; R. R. Miller, Precision Metalsmiths, Inc. and President of the Institute. Standing: G. W. Cannon, Jr., Cannon-Muskegon Corp.; Ted Operhall, Misco Precision Casting Co.

AMERICAN DIE CASTING INSTITUTE, INC. . . 1958 annual meeting was held at the Edgewater Beach Hotel, Chicago, September 10-11. Newly elected executives greeted at the opening session were: R. C. Strassman, Badger Die Casting Corp., Milwaukee, president; vice-president, G. C. Curry, Dollin Corp., Irvington, N. J. and David Laine and W. J. Parker, American Die Casting Institute, re-elected secretary and treasurer, respectively. Laine announced die casters educational program was in effect at Pennsylvania State University and plans to extend educational assistance to other engineering schools were made. Program includes two annual scholarships, a cash award program, teaching aids and other benefits.

Die casters, representing 122 member companies, indicated a definite pickup in the output of their industry. They predicted 1958 production will total 315,000,000 lb of aluminum die castings in comparison to 376,000,000 lb the previous year. Production efficiency was the keynote of the meeting devoted to evaluation of new techniques being developed through research. Among new developments covered were improved die and core materials; new process and production control apparatus; more efficient lubricants and lubricators; vacuum die casting and basic research and alloy development in cooperation with American Zinc Institute. The automotive industry represents a potential annual market for 700 to 800 million lb of aluminum castings in a 6 million car year.

Applications which are being developed in and for this industry are; engine blocks, cylinder heads, manifolds,

pulleys, rocker arms, oil and water pumps, wheels, gear cases, transmission parts and brake drums.

The meeting feature was presentation of the Annual Doehler Award, highest honor of the die casting industry, to Gustav Nyselius, Mt. Vernon Die Casting Corp., at the closing banquet. The award consisting of a

Gustav Nyselius

certificate, a plaque and a cash honorarium, was presented by A. T. Lillegren, Madison-Kipp Corp., representing the Institute Board of Directors. Lillegren cited the many contributions made by Nyselius to advancement of the die casting industry. In particular, it was stated the Doehler award specifically recognizes initiation of the concept of advancing die casting techniques by cooperative effort and pooling of patentable developments through the Die Casting Research Foundation.

City Pattern, Foundry and Machine Co. . . . Detroit, has been re-organized as City Pattern, Foundry Machine Co., Inc. B. H. Fisher is president; V. C. Reid, vice-president; H. S. Ball, sales manager and Robert Procter, controller. No change will be made in method of operation and they will continue to manufacture wood and metal patterns, non-ferrous castings and general machine work.

Claude B. Schneible Co., . . . Detroit, announced the reorganization of their firm following the acquisition of additional working capital. C. N. Dold is the new chairman of directors; G. C. Schreiber new president and general manager; A. S. Lundy, vice-president and R. G. Whitehead, secretary and sales manager. Schneible has produced some

modern castings

FOUNDRY FACTS NOTEBOOK

Metallurgy of Gray Cast Iron

Foundry Facts Notebook is designed to bring you practical down-to-earth information about a variety of basic foundry operations. As the name implies, this paper is prepared for easy removal and insertion into a notebook for handy future refrence.—Editor

Part 3: Influence of Silicon and Cooling Rate

BY C. H. MORKEN
Vice-President & Works Manager
The Kennedy Valve Mfg. Co.
Elmira, N. Y.

This is the third chapter discussing the metallurgy of gray cast iron to appear in Modern Castings Foundry Facts Notebook. Chapter 1: What Causes Graphite Formation, was published in the January issue while the April issue carried Chapter 2: Phase Transformations During Cooling.

In this chapter the discussion of phase transformations is extended to explain the influence of silicon and cooling rate on decomposition of iron carbide.

With normal cooling of cast iron silicon exerts its influence to break down iron carbide and liberate graphite. The important thing to realize is that silicon exerts its influence on ALL of the iron carbide, whether it be free carbide or sandwiched layers in pearlite.

It follows, then, that if enough silicon is present and given enough time–temperature, all of the free carbides represented in diagram (right) disapper, being converted to graphite and ferrite. At the same time the cementite that is present in the pearlite is decomposing in the same manner, also producing graphite and ferrite.

The graphite that is formed below the critical temperature is known as secondary graphite. It is likely to be finer in size than the primary graphite that was formed early in solidification.

The ferrite that separates out is a solid solution of silicon in iron. It is very soft and ductile; about two-thirds as strong as pearlite; runs about 125-130 Bhn; smears badly under friction load and smears and drags under the tool in machining. Other than in castings for special purposes, this ferrite is usually considered an undesirable constituent in cast iron. It also indicates that the silicon was too high for the job.

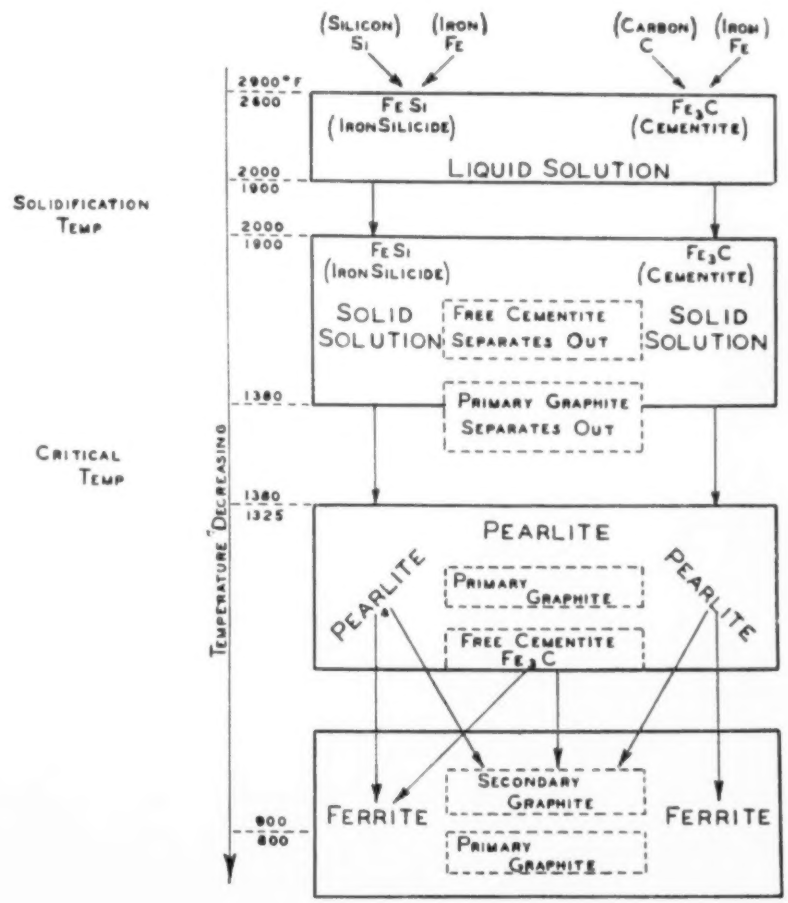
It could be assumed from diagram below that the process of graphitization continues on down to room temperature, but such is not the case. Theoretically this may be true but for all practical purposes there is no further reaction below about 800 F.

The reactions shown in the diagram indicate that the structure of cast iron can be controlled by:

1) Governing the cooling rate down to the critical temperature, thus controlling the formation of primary graphite.
2) Governing the cooling rate below the critical temperature, thus controlling the decomposition of pearlite and the formation of secondary graphite.
3) Adjusting the silicon content of the iron to suit the natural cooling rate of the casting in the mold.

Graphite Carbon

To these, some other factors can be added. Most of the commercial



cast iron runs from about 2.75 per cent to 3.80 per cent total carbon, the most common range being 3.00 per cent to 3.60 per cent. Most of this carbon will be present as graphitic carbon.

The graphite occurs in a random pattern which interrupts the crystal structure of the iron. It serves to create cleavage planes between the grains of the iron. This graphite makes pearlitic cast iron weaker than pearlitic steel, causes pearlitic cast iron to be brittle while pearlitic steel is ductile and produces a gray appearance when fractured.

The more graphite there is present, the more frequent are the interruptions of continuity in structure. So the higher the graphitic carbon, the weaker and more brittle the iron will be.

Total Carbon

At 2.00 per cent silicon the pearlite of cast iron contains about 0.66 per cent carbon. If no free carbides are present the 0.66 per cent would represent all of the combined carbon present. A chemical analysis would reveal the total carbon. The difference between the total carbon and combined carbon would be the amount of graphitic carbon present. Table II has been prepared by subtracting the 0.65 per cent value for combined carbon in pearlite from the total determined by chemical analysis to show the graphitic carbon present.

Table II

Total Carbon	Combined Carbon	Graphitic Carbon
%	%	%
2.75	0.65	2.10
3.00	0.65	2.35
3.25	0.65	2.60
3.50	0.65	2.85
3.75	0.65	3.10

One could expect that the iron containing 3.10 per cent graphitic carbon would show the lowest strength, and that the irons above it would be progressively stronger because there is progressively less graphitic carbon to exert its weakening influence—and that's about the way it is.

How is the total carbon regulated? Most cast iron is melted in a furnace known as a cupola. This is a vertical shaft in which a coke fire is ignited at the bottom. Upon this, alternate layers of iron and coke are laid until the shaft is full to the charging door. A measured blast of air is then blown in and the iron melts. As fast as it melts, weighed amounts of iron and coke are added through the charging door, usually alternating a charge of iron and a charge of coke. This situation is conducive to providing carbon for the iron to absorb.

Fortunately, controlling the air blast rate with respect to the size of the furnace and the melting rate assists materially in controlling the amount of carbon picked up by the iron as it melts. The simplest thing to do to produce lower total carbons is to put low carbon materials into the charges. Steel is commonly used. The combination of steel, controlled air blast, and to some degree coke quality, is used to produce whatever carbon level is required.

To summarize, the properties of a gray iron casting can be controlled by:

1) Governing the cooling rate down to the critical temperature, thus controlling the formation of primary graphite.
2) Governing the cooling rate below the critical temperature, thus controlling the decomposition of pearlite and the formation of secondary graphite.
3) Regulating the silicon to producing a pearlitic structure in accordance with natural cooling rate of the casting.
4) Regulating the total carbon so as to produce the desired strength, hardness and machinability.

The first two of the above are classed as "noncommercial" because there is no practical and economical way to accomplish them. To do the first would require pouring the mold while it is in a furnace which was at a temperature well above 2000 F. Thus, after pouring, the freezing rate of the casting and its cooling rate down to the critical temperature could be controlled by controlling the cooling rate of the furnace. This is theoretically possible, and it has been done on occasions, but it is not practicable.

There is a little more latitude in the second case. The casting could be poured in the foundry in the ordinary manner, then either the mold and its casting or the stripped casting could be rushed into a furnace. Thus, the cooling rate down to the critical temperature would be the natural one of the mold-casting system; while the cooling rate from the critical temperature down to about 800 F could be controlled at any desired rate. This also is done on occasions, but it is not an attractive way to make castings.

The alternative, then, is to regulate the silicon and the total carbon to suit the natural cooling rate of the casting in the foundry. The same result can be obtained at an increase in cost by subsequent heat treatment.

Inoculation

While a great many foundries can and do confine themselves to carbon and silicon control, still other factors can be employed further to modify and enhance the properties of cast iron. One of the most interesting of these is controlling the form and distribution of the graphite. This is done with a process known as inoculation, which is the addition of a graphitizing agent to the molten iron. Silicon is a graphitizing agent.

Instead of melting raw materials to produce a 2.00 per cent silicon iron, for instance, procedures are altered to produce a 1.50 per cent silicon iron. The other 0.50 per cent silicon is added to the molten iron just before pouring into the molds. Results are surprisingly different. Generally speaking, the iron will be tougher and stronger. Microscopic examination will show that the explanation lies in the graphite form and in its distribution. Graphite is finer and more uniformly distributed, thus giving the pearlite more chance to exert its influence upon the strength.

Most foundries today inoculate with one graphitizing agent or another. Some of them use ferro silicon or calcium silicide; others use proprietary alloys produced for the purpose. Excellent cast iron is produced in this manner and it is produced in a range of compositions to develop a range of physical properties.

of the largest systems for dust control and ventilation in the industy. Reorganization and refinancing will enable them to maintain a strong competitive position, to develop new products and expand its sales force.

Wheelabrator Corp., . . . Mishawaka, Ind., formed the Techline Division as a result of acquiring former Crandall Engineering Mfg., Inc. of Vicksburg, Mich. The division will manufacture and sell precision finishing machines and wet blast equipment. Complete experimental and demonstration laboratories also will be maintained in Vicksburg. G. H. Lieser will be field-sales manager; Roy Romine, chief engineer and Lee Stevens, director of process engineering.

Swayne, Robinson & Co. . . . Richmond, Ind., has announced the development of a molding process aimed at production of precision castings. The process uses the CO_2 method of curing sand. Castings produced are said to hold plus or minus 0.015 of an inch. Molds are hardened on patterns before the draw providing a close fit to casting surfaces. But application will be to jobs which require close tolerances for machining. Process is said to offer dimensional accuracy of shell castings, combined with lower cost of green sand.

Turbo-Cast, Inc. . . . Los Angeles, purchased a new 100,000 sq ft plant marking the first step in a complete reorganization plan in the investment casting foundry.

F. C. Howard, Jr., president, stated, "the reorganization is aimed at increasing the capacity of Turbo-Cast by approximately 1000 per cent and is to be completed shortly with production transition being scheduled to prevent interruption of current work."

Turbo-Cast is well-known to the western and southwestern aircraft and missile industries. Although production is concentrated in high-temperature cast-steel applications, the foundry also casts non-ferrous alloys.

National Research Corp. . . . Cambridge, Mass., has been awarded a government contract of $460,000 to design, construct and test-operate one of the largest vacuum furnaces in the United States. This vacuum skull furnace will be used in melting titanium, one of the strategic metals of interest to the country's defense program.

B & T Machinery Co. . . . Holland, Mich., announced the opening of a research laboratory for investigation and testing of new developments for the die casting industry. The labora-

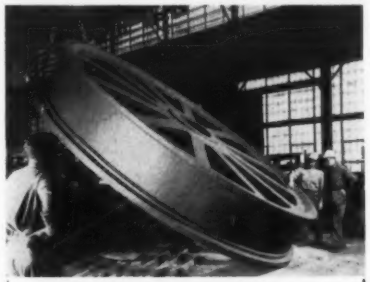
tory is housed in a separate building equipped with complete apparatus for vacuum casting of both zinc and aluminum. Work is being done on methods of producing zinc and aluminum die castings under vacuums of 25-28 in. of mercury with simple units that can be attached to most die casting machines.

This program will also include development work on die temperature control units, automatic spray lubrication, automatic casting ejection, preladling and automatic ladling of aluminum.

WaiMet Alloys Co. . . . Detroit, division of Consolidated Foundries & Mfg. Corp., announced their entry into the vacuum melted alloy field. Roger Wairdle, president, said that an exclusive sales agreement was made with Allvac Metals Co., Monroe, N. C., for the sale of vacuum melted alloys to the castings industry.

Roger Metzler, sales manager of WaiMet, will be in charge of market development in this new field. J. D. Nisbet, president and technical director, Allvac Metals, is one of the pioneers in this field. He directed vacuum melting research activities at both General Electric and Universal Cyclops Steel Corp.

Sonken-Galamba Corp. . . . with warehouses located in Kansas City, Kans.; North Miami, Fla.; and Gardena, Calif., has been named a distributor of aluminum pig and alloy ingot for Reynolds Metals Co.



This giant steel casting is one of eight sheaves being cast at the Coraopolis, Pa., foundry of Blaw-Knox Co. for the world's longest vertical lift bridge—the Arthur Kill railroad bridge connecting New Jersey and Staten Island. Weighing 60,000 lb unmachined, the casting is over 16 ft in diameter and 31 in. deep. The sheaves will carry 1-1/2-in. diameter wire rope that will raise and lower the 558-ft long span. The American Bridge Div., United States Steel Corp., is fabricating and erecting the steel work for the bridge.

How long?—5 weeks!

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Control for Steel Melting

Continued from page 30

bon and other deoxidizers present. In general, it is desirable to tap steels at the highest possible carbon content for maximum cleanliness. This is why rail steels are no longer recarburized and why silicomanganese with its lower carbon content is widely used for blocking the medium and lower carbon heats in the basic open hearth. It is particularly important when final carbon specifications permit keeping tap carbon above 0.20 per cent. Below this value the oxygen content rises rapidly with decreasing carbon and will tend to increase the amount of oxides present in the final steel.

In addition to oxygen, sulphur content is important since about 50 per cent of the inclusions are sulphides. Therefore, low sulphur content is desirable. The highest quality steels in the wrought industry are made in the basic electric furnace partly because of its ability to attain very low sulphur contents.

If total sulphur and oxygen content were the entire story in steel quality it would be a simple one, but this is just not so. It is the structure, the shape, and the distribution of the final oxygen and sulphur contents or inclusions that markedly affect steel properties.

Inclusion Formation

The effect of deoxidization on the formation of inclusions and ductility in cast steels has been studied by Sims and Lillequist, Sims and Dahle, Crafts and Egan[15] and others.

In Grott's discussion of the Sims and Dahle paper he suggests that calcium added to the heavy aluminum deoxidation would make it more effective and reliable in preventing intergranular sulphides. Among the calcium alloys most popular in steelmaking are: CaSi—about 31.5 per cent Ca, 62.5 per cent Si, and CaMnSi—about 17.5 per cent Ca, 16.0 per cent Mn and 56.0 per cent Si. Either of these are generally added to the ladle after the aluminum addition in amounts from 3.5 to 5 lb/ton to ensure good ductility.

A parallel between the wrought and the cast industry is found in the fully killed steels made to a range of from 0.20 to about 0.40 per cent final carbon. The solidification of these steels when fully deoxidized with aluminum appears to produce intergranular sulphides which yield poor ductility and hot tearing in castings and poor surface-rollability in wrought steels. Engquist[16] has recently reported his work and suggests a lower carbon content and higher manganese content for carbon cast steels to alleviate hot tearing.

Finishing practice is a complex and controversial subject. To maintain constant quality, the following points are desirable:

Furnace Finishing Practice

1) *Level of Oxidation*

Have a consistent finishing practice which means proper melt down carbon, good carbon boil, proper ore or gaseous oxygen additions, proper bath temperature sometime before tap, proper tap carbon level and as uniform a slag composition as possible. This should provide a constant level of oxidation which may be an important factor in sulphide inclusion formation.

2) *Furnace Deoxidation*

a) Add a substantial portion of deoxidizers to the furnace as a combination alloy preferably of silicon and manganese. This will provide for fast solution of alloy and a more rapid removal of inclusions in the furnace and during tapping. Tap as rapidly as practical to prevent hydrogen pick-up.

b) Do not over-deoxidize in the furnace but have enough deoxidation present to prevent a reboil if a silicon type alloy is used for blocking.

c) Have a clean well shaped tap hole, as smooth a tapping stream as possible and a uniform blocking and tapping interval.

3) *Ladle Deoxidation*

a) Aluminum to control pinhole porosity and other alloys to control sulphide distribution and pinhole porosity should be added to the ladle in the proper amount for a given practice.

b) When shanking, with attendant long holding times at high temperatures in the bull ladle, remember that aluminum will oxidize in the ladle so that additional deoxidation may sometimes be required in the shank ladles for porosity and inclusion control.

4) *Pouring*

When possible, have a consistent pouring temperature for a given casting technique; this requires a knowledge of ladle temperature drop. The use of the immersion thermocouple for accurate ladle temperatures should provide data which if applied can help maintain consistent pouring temperatures.

Melting Units

This chemistry of modern steel melting is being practiced in three basic type melting units—open hearth, electric arc and induction furnaces. The more important recent changes in construction, oper-

ation and use of these units are summarized as follows:

Open Hearth Furnace

The open hearth with its shallow bath, its reverberatory type roof, and its checker system designed to provide highly preheated air, has experienced only minor changes in design over the years. Improved refractory use has been the keynote, the over-all aim being to develop for each part of the furnace a refractory life which will, with minimum or single repair, last the life of a campaign. In basic furnaces the bottom pan is now shaped to provide for a uniform thickness of bottom material. No heavy corner build-up is deemed wise. A thin uniform bottom will keep the high temperature zone close to the steel bath, thus preventing the penetration of errosive oxides. Basic bottom materials are of highest possible magnesia content.

Improved methods of blowing keep the checkers clean throughout the campaign. The use of steam jets under the rider arches to prevent a build-up of flue dust has been most helpful. It is not uncommon now to find a furnace operating as sharply during the last heat of its campaign as it did during the latter part of the first week. Most important has been the sealing of the entire checker system by spraying both inside and out with refractory cements. This prevents air infiltration, and thus, maintains highest flame temperature which is the driving head of the process.

Improved burner design and the use of oxygen for combustion and decarburization has improved tonnage rates.

Electric Furnace

The electric furnace with its capability for rapid heat-up and ease of shutdown is a most useful tool in the steel foundry industry. Improved furnace design; higher side walls; larger cubic capacity to handle light scrap; fast top charging; amplidyne or similar arc controls; and higher transformer capacity have all led to improved production rates for the arc furnaces. Since this melting unit is primarily scrap consuming, the new work on the

Continued on page 122

Control for Steel Melting

Continued from page 122

fluidized-bed, reduction of iron ores with hydrogen is of great interest to the electric furnace operator. Recent announcements have estimated costs for this process at from $13 to $20 per ton over the cost of a metallic ton of iron in ore. Depending on the cost of ore this could mean some very reasonably priced scrap. "This may also mean integrated steelmaking may be permitted with iron ore as a source of iron units independent of the scrap market."[1]

Induction Furnace

Fortunately the induction furnace has been adaptable to melting in a vacuum chamber. Thus it has opened many new fields in super alloy research. This type of melting eliminates gases, improves mechanical properties and provides close control over composition. Therefore it will be a useful and interesting tool for the castings industry.

Steel Castings

So much for the chemistry of steel melting; let us take a look at the cast steel industry, its present production, and its future growth.

In 1956 approximately 1,400,000 net tons carbon steel, 480,000 net tons of low alloy steel and 41,000 net tons of high alloy steel castings were shipped. This amounts to a total of 1,921,00 net tons. In all probability about 3,500,000 net tons of steel were melted. The most favorable growth rate—9 per cent per year[2] has been indicated for the high alloy field. This means a continued need for basic electric furnaces with improved alloy recovery and control as an important factor.

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product report . . .

Silicon rubber gaskets . . . at a fraction of their regular price are being made for their own use by Tru-Scale, Inc., Wichita, Kans. The company discovered that mold costs involved in producing limited quantity of molded rubber seals or gaskets needed for their epoxy-glass compression and vacuum molds, priced them out of range. The problem was finally solved with Silastic RTV, a silicone rubber that vulcanizes without heat or pressure manufactured by Dow Corning Corp., Midland, Mich. After routing a groove of the

proper diameter out of birch-faced plywood, sanding, sealing and rubbing with wax; the material is poured in and allowed to set overnight. Com-

pany has used this "do-it-yourself" method to produce silicone rubber rings up to 48 in. in diameter. Some of the rings have seen as many as 30 cycles without deterioration.

For Manufacturer's Information Circle No. 946, Page 7-8

Circle No. 993, Page 7-8

classified advertising

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Sell nationally-known line of quality controlled foundry products—core oils and binders, washes, sand additives and compounds, etc. Major manufacturer, now doing a multi-million dollar sales volume in a few states, is undertaking an expansion program. Men with some foundry "know-how" preferred. This is a full-time opportunity with a challenging financial future. Our organization knows of this ad. Reply in strictest confidence giving educational background, marital status, etc.

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Immediate opening with Metals Processing Division of Curtiss-Wright Corporation, located in Buffalo, N. Y., to plan and direct all operations of Division's foundry which specializes in heat and corrosion resistant steel castings. Complete responsibility for all activities. Excellent salary and executive benefits. Send detailed resume including salary requirements to:

T. W. COZINE
Mgr., Executive and Technical Placement, Dept. MD-2
CURTISS-WRIGHT CORPORATION, WOOD-RIDGE, N. J.

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Experienced in sand and quality control, age 35-45, for Upper Midwest company. Send resume stating experience, education, qualifications and availability. Salary open, replies confidential. **Box E-47, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

FOUNDRY SALES SPECIALIST

Well-established AAA1 South Central Foundry with up-to-date equipment—producer of gray and nodular irons—has excellent opportunity for the **RIGHT** man. He must be a successful foundry salesman with imagination and have no fear of hard work. If you feel you are this man, write us sending full resume and financial requirements. Reply to:

Box E-43, MODERN CASTINGS, Golf and Wolf Rds. Des Plaines, Ill.

Positions Wanted

Can you use 40 years of practical foundry experience? Long-time foreman and supervisor seeks outside job as trouble shooter, adjuster, or plant protection. Well qualified to price castings. Hard working and active man; member AFS 11 years. Thirty-eight years with last employer. Prefer Dayton, Ohio area, but will relocate. **Box E-44, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

SPECIALIZED GERMAN ENGINEER for mechanization of foundries wants contact with distinguished American company specialized for the construction of foundry-machines, which wants its interests in Europe cared for by an experienced expert. Age 35 years, independent, living in Hamburg. Reasonable time getting acquainted with work in factory appreciated. Offers under **8615 to WILLIAM WILKENS WERBUNG, Hamburg 1, Germany.**

Foreign foundrymen available—

1) Australian foundrymen with chemical engineering degree, served—junior metallurgist in alloy steel; apprentice molder and management trainee in steel foundry; chief metallurgist in light organic and inorganic materials and sales development engineer with non-ferrous company manufacturing sheet and extruded products. **Box E-45**
2) Delhi, India, patternmaker with five years training in machine tool phototype factory; attended Punjab University; Artisan Training School. Seeking position as industrial trainee. **Box E-46**

MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.

For Sale

ELECTRIC ARC FURNACES FOR SALE
Two — 2000-lb side-charge furnaces complete with transformers, extra tops and electrodes. Low price for quick sale. **FRED H. WUETIG, 7445 South Chicago Ave., Chicago 19, Illinois. HYde Park 8-7470.**

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BACK VOLUMES — Wanted to buy for cash of foundrymen, **TRANSACTIONS** American Foundrymen's Society and other scientific technical Journals, **A. S. ASHLEY 27 E. 21, N. Y. 10, N. Y.**

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product report . . .

Gray iron and alloyed high-strength iron foundry, North Jersey Foundry Co., Little Falls, N. J., is using four Model HA "Payloader" tractor-shovels manufactured by Frank G. Hough Co., Libertyville, Ill., in handling sand, coke and slag and for general foundry maintenance.

Handling coke in charging operation.

Three of the units are employed to handle 90 tons of floor sand twice daily. This requires six hours. The

Sand is carried to simplicity shakeout.

2000-lb capacity units haul sand 300 ft to the shaker where it is remulled and returned to 12 molding areas.

For Manufacturer's Information Circle No. 947, Page 7-8

modern castings